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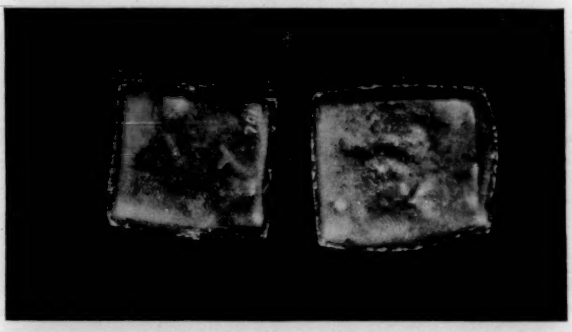

Specimens of Faraday heavy glass.

THE Royal Institution of Great Britain has presented to The Franklin Institute of the State of Pennsylvania the souvenirs of the great Faraday which are pictured in this issue of the JOURNAL.

The following extract is taken from a letter from Sir William H. Bragg, Secretary of the Royal Institution: ". . . We are taking the opportunity of sending you one or two specimens of the coils with which Faraday worked at the time when he made his electro-magnetic discoveries, and specimens also of his heavy glass. I hope these things reach you safely and that they may be acceptable to your members. . . . . "

It is needless to say that this donation was most acceptable to the Institute. The coils and the glasses are on permanent display in our cabinets and will ever be counted among our most valued possessions. THE EDITORS.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

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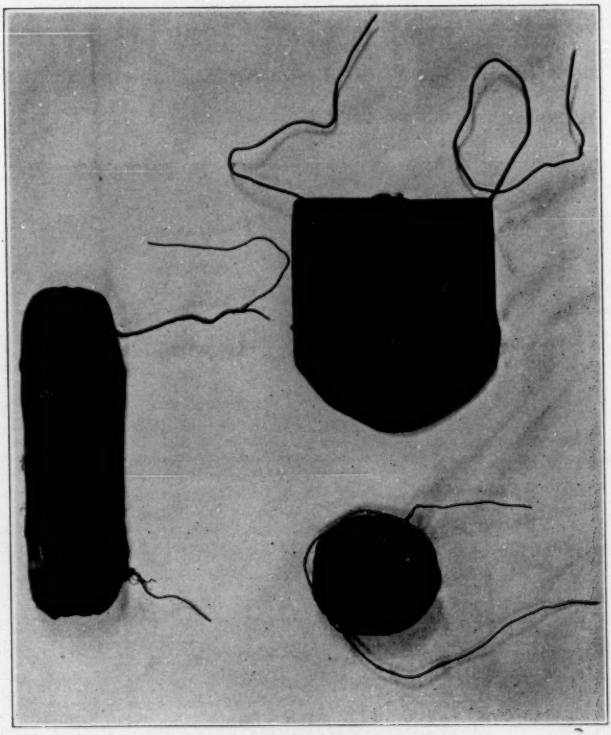

Faraday coils.

UNUSUAL ENGINEERING FEATURES OF THE CONOWINGO DAM AND POWER PLANT.*

BY

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Member of the Institute.

WITH the exception of the St. Lawrence, the Susquehanna River basin is the largest and most important on the Atlantic coast. The total drainage area receives the run-off from 47 per cent. of the total area of the State of Pennsylvania, 13 per cent. of the total area of the State of New York and 2 per cent. of the total area of the State of Maryland. The entire area of the basin, 27,400 square miles, is divided as follows: 21,060 square miles (77 per cent. of the drainage area) in the State of Pennsylvania; 6080 square miles (22 per cent. of the drainage area) in the State of New York, and 260 square miles (1 per cent. of the drainage area) in the State of Maryland.

The distribution of this drainage area is shown graphically in Fig. 1, which indicates very definitely how large a portion is within the boundaries of the State of Pennsylvania. It is not universally appreciated that this basin extends in a northerly direction almost to Utica in the State of New York and westwardly beyond Altoona in the State of Pennsylvania.

Records of the United States Weather Bureau show that the annual precipitation over this area varies from 31.4 to 44.3 inches with a mean value of 39.4 inches.

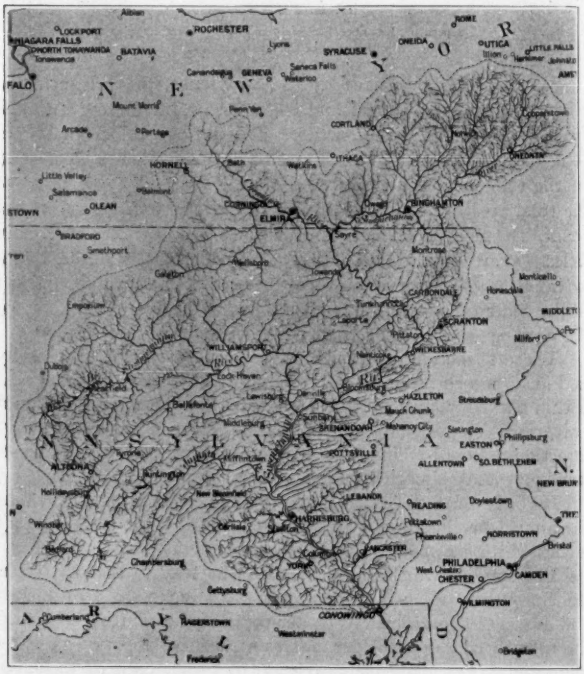
The run-off, which eventually finds its way to the sea, from the Susquehanna River, varies from 16.6 inches to 29.1 inches and averages approximately 55 per cent. of the rainfall. During the months of August, September and October the run-off is at a minimum, varying from 5 per cent. to 30 per cent. of the rainfall with an average of about 15 per cent. Like all other Pennsylvania streams the natural run-off of the Susquehanna River is extremely variable daily, weekly and seasonally.

The figures of run-off in inches and percentage do not completely illustrate the extreme variation in the flow of the Susque-

* Presented at the Stated Meeting held Wednesday, December 15, 1926.

hanna River. To supplement this information hydrographs of the river from 1891 to 1925 have been plotted in Fig. 2. These hydrographs were plotted on the data obtained from stream measurements at Harrisburg. The increased drainage area below

FIG. 1.



Harrisburg results in an increase in flow of about 12½ per cent. Special ordinate markings have been inserted to correct the flow as measured at Harrisburg over a period of thirty-five years to equivalent flow at Conowingo.

The initial installation of seven units requires about 42,000 second feet for full output. From the graph it will be noted that

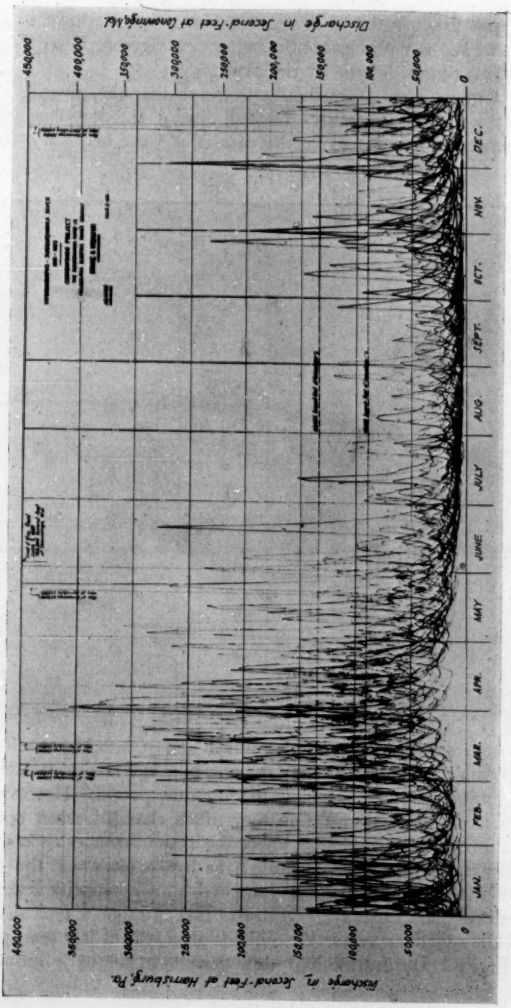
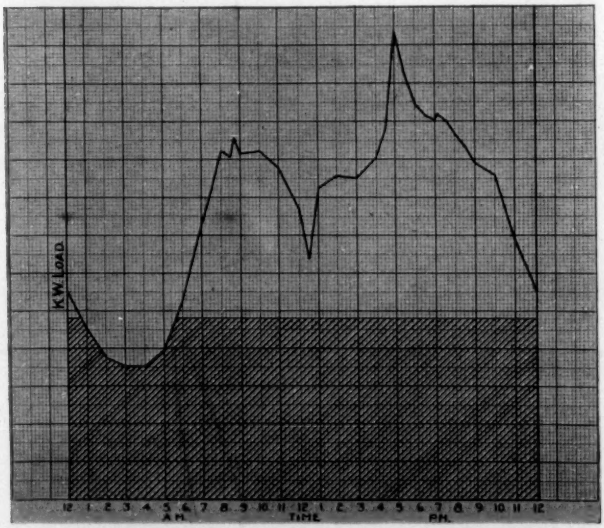

Discharge in Second-Feet at Conowingo Dam
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
Discharge in Second-Feet at Harrisburg, Pa.
450,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0

FIG. 2.

the first five months of the year on an average supply this total output; the remaining months being considerably lower than the total maximum output of the plant.

It might seem from this hydrograph that the capacity of the plant would be seriously reduced during the low-flow period. Admittedly, this would be the case if it were necessary for the

FIG. 3.

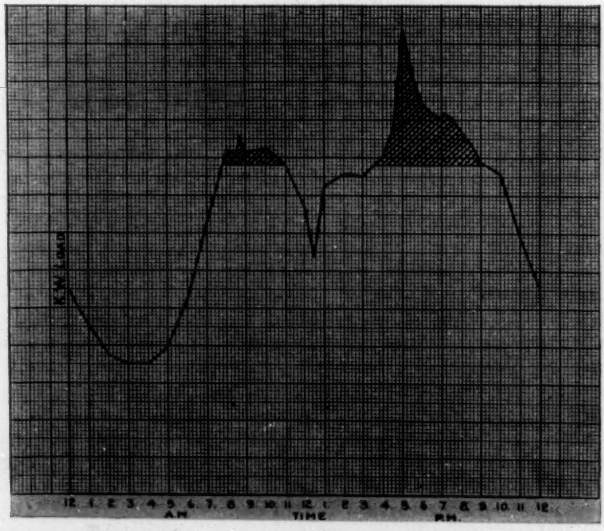


plant to supply the service unaided and it would therefore be impossible to develop it for firm power in quantities greater than the limitation imposed during the low-flow period. However, the status of the hydro plant is very much changed when operated as a unit in a large system where the system demand is considerably greater than the capacity of the hydro plant and the difference between this demand and the hydro plant capacity is supplied by steam plant capacity. To clarify this situation a typical winter weekday load curve for the Philadelphia system has been plotted in Fig. 3. During the high-flow periods in the early months of

the year, when there is sufficient water, the hydro plant will be operated as a base load plant carrying full load for practically the entire twenty-four hours of the day. This is represented in Fig. 3 by the cross-hatched portion of the load curve. The remainder of the load will be carried by steam plants.

If it is assumed that in the month of December the run-off is

FIG. 4.



as represented by one of the hydrographs that shows a very low flow, then there will be insufficient water to operate the plant as shown in Fig. 3. If the plant were operated as a base load plant, its capacity would probably be reduced to one-third of that shown in Fig. 3. However, the energy produced by this same amount of water can be utilized on the peaks of the load curve as illustrated in Fig. 4, thus obtaining a higher plant capacity with the energy available. The cross-hatched section at the top of the load curve in Fig. 4 represents the part of the load carried by

the hydro plant; the remaining unhatched section being carried on steam plants.

This method of utilizing the hydro-electric plant as a peak load plant means that during the period of high load demand on the hydro plant quantities of water much in excess of the river flow will be utilized. This will be accomplished by drawing on the storage reservoir back of the dam. As the load on the hydro plant is decreased, and finally the plant shut down, the reservoir is again filled up by the flow of the stream so that the total flow of twenty-four hours is utilized in about eight hours, which is equivalent to tripling the water peak capacity.

A further inspection of the load curve in Fig. 4 during the afternoon shows that this is triangular in shape. It is a well-known fact that the area of a triangle is one-half that of a rectangle having the same base and altitude. The same amount of total water quantity will therefore produce twice the altitude in a triangle as it would in a rectangle. The multiplier of three was obtained by merely using the water capacity for twenty-four hours in eight hours, as a rectangular load. Considering, however, that this is utilized in a triangular-shaped load instead of a rectangular-shaped load, the multiplier for obtaining the available capacity on a triangular-shaped load is twice that for the rectangular-shaped load, or six times the twenty-four-hour steady load water capacity. If, therefore, the minimum steady capacity is 30,000 kilowatts, the peak capacity utilized in the manner indicated in Fig. 4 would be six times 30,000 or 180,000 kilowatts.

The method of operation outlined permits the financial development of this stream since it is possible to utilize a large percentage of the entire plant capacity at all times irrespective of the quantity of water flow, and thus a minimum amount of steam plant capacity is required to supplement the hydro-electric plant capacity.

Quite possibly there is a question in the minds of many as to why the lower reaches of the Susquehanna River are only now being developed for power when this project has engaged the attention of engineers and capitalists for the last forty years. The answer to this, of course, is that given in the preceding load curve demonstration in Figs. 3 and 4. It was absolutely impossible to develop this location financially until the demand for power in adjacent territory had grown to such an extent that the

output of the hydro-electric development could be completely absorbed in the system without large and expensive relay steam generating capacity for use during the low-flow periods.

Early in March, 1926, The Philadelphia Electric Company through its subsidiary, the Philadelphia Electric Power Company, and the latter's Maryland subsidiary, The Susquehanna Power Company, under Federal license approved February 20, 1926, began construction of a dam and power-house with an initial wheel capacity of 378,000 h.p. Five possible sites for the Conowingo Dam were examined and an exhaustive study made of the power available and the total cost of development at each site. The site as finally adopted is located approximately two miles below the village of Conowingo, Md., and is far enough north to permit the use of the accepted maximum grade on the railroad. A lake will be formed at an elevation of 108.5 feet above sea-level extending about fourteen miles upstream. This storage reservoir is shown in Fig. 5.

The present Conowingo bridge over the Susquehanna River will be flooded, and it is therefore necessary to provide some adequate structure to replace the submerged bridge. The final decision was made to place the bridge on the top of the dam structure about two miles downstream from the present bridge. This necessitates the rebuilding of a section of the state road between Philadelphia and Baltimore. The relocated road passes over the dam as shown by the heavy line in Fig. 5, beginning near Porter Bridge and ending west of Darlington.

The storage reservoir is included back of the dam, shown by the heavy line aforementioned, up to the tailrace discharge of the Holtwood hydro-electric development, shown by a line across the river between Lower Chanceford and Martick counties in Pennsylvania.

The Columbia and Port Deposit branch of the Pennsylvania Railroad Company is located along the east side of the Susquehanna River at an elevation that will be flooded after the dam is built. For this reason it is necessary to relocate this railroad from just below Holtwood to the Conowingo Dam so that the new road bed will be above the 108.5-foot elevation of the pond. To preserve the minimum grade of .35 per cent. that was finally accepted by the railroad company, it was also necessary to relocate the railroad from Conowingo to Port Deposit. This railroad

relocation is mentioned, although there are no new or unusual features in it, merely as an indication of some of the incidental expenses necessary in the development of this project that are

FIG. 5.

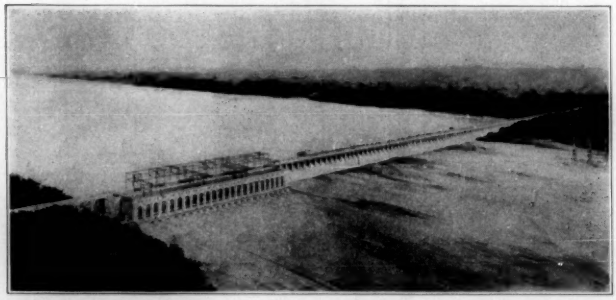
directly chargeable to it but are really not part of the installation fundamentally necessary to power development.

It will be noted that while the dam and power-house are located in Maryland, the upper half of the reservoir is in the

State of Pennsylvania. This required the joint action of the Public Service Commissions of the two states as well as the license from the Federal Power Commission since the Susquehanna is considered a navigable river.

Power will be transmitted from the Conowingo development to the City of Philadelphia initially by means of two 220,000-volt three-phase transmission lines, each capable of carrying the entire initial output of the plant. This paper has to do more with the

FIG. 6.



hydro-electric development, and it is not intended to take up any details of the transmission line from the project to the City of Philadelphia.

To give a concrete idea of the hydro-electric project, the appearance of the dam and power-house when construction work has been completed is shown in Fig. 6. With this picture in mind the details as developed later will be more readily understood. Fig. 6 is a view taken from the hillside on the west bank of the river with the power plant in the left foreground.

The oil switch gear for the transformers and transmission lines is located on the roof of the power station. The section of the dam nearest to the power station contains the regulating gates which must be used frequently to control the elevation of the water in the pond. The remaining gates in the dam, which are located at an elevation below the highway over the dam, are flood gates to allow over 880,000 second feet to pass in event of floods.

It will be noted that toward the right-hand side of the dam the section changes. This right-hand section does not contain

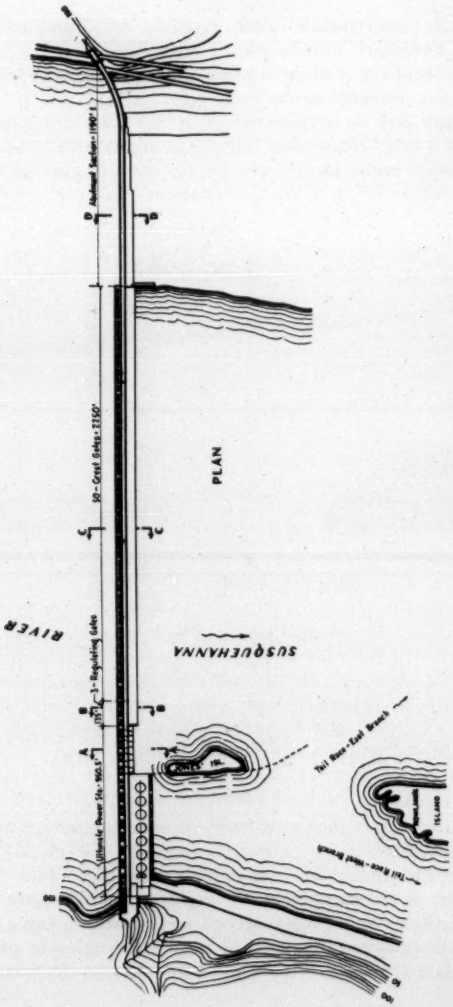
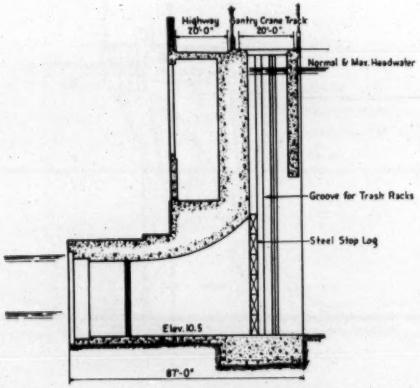

PLAN
RIVER
SUSQUEHANNA
Tail Race - East Branch
Tail Race - West Branch
ISLAND

FIG. 7.

gates and is merely a retaining wall from the point of change in the structure to the tie-in with the east hillside.

The gates are operated by three sixty-ton gantry cranes running on a track beside the highway. One of these gantry cranes is shown near the left-hand end of the dam and the other near the right-hand end of the dam. The transmission line will leave the steel structure on the roof and either cross in one span to the other side of the river or be brought to Rowland's Island, which

FIG. 8.



SECTION "AA"

will be shown later in the tailrace drawing, and then make a right-angle turn across the river to the east side. The decision as to the type of crossing has not yet been made.

With this general picture in mind the design details of the plant will now be developed.

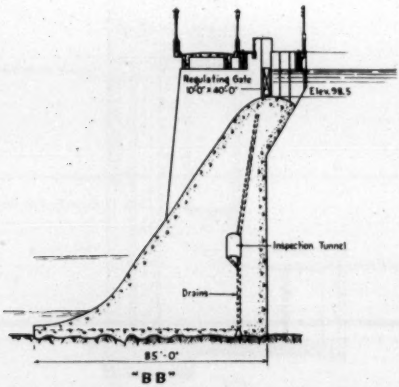
A plan view of the hydro-electric plant dam and wing wall is shown in Fig. 7. The entire power plant is 950.5 feet long; the section containing the three regulating gates next to the power plant is 135 feet long; the section containing the 50-crest gates for relieving flood water is 2250 feet long, and the abutment wall section is 1190 feet from the end of the crest gates to the point where this wall ties in with the rock formation in the hillside.

Section *AA* (Fig. 8) is the part of the power plant in which

the future units will be installed. The power-house will not be built for this section of the dam at present, but the dam structure will be so built that this section of the power-house can be readily added. These four penstocks for the future units will be used as a waterway for the river during the final closure of the dam.

Section *BB* (Fig. 9) shows a gravity section of the dam through the regulating gates. The roadway bridge over the dam is shown at the left top of this section. It will be noted that the

FIG. 9.



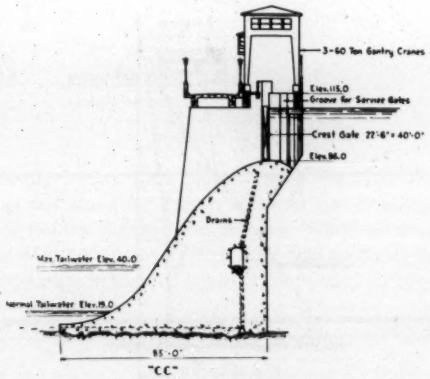
dam crest for the regulating gate is at elevation 98.5 feet. It is intended to use these gates when the river flow is only slightly in excess of the turbine demand so that the water back of the dam may be conserved and that the gates need not be operated as frequently as would be the case if larger gates were used.

Cross-section *CC* (Fig. 10) is that of the spillway section. The highway bridge structure is the same as in cross-section *BB*. It will be noted, however, that the greatest elevation of the dam is 86 feet, or 12.5 feet lower than the regulating gate section. Each of these gates will discharge about four times as much water as the regulating gates. The gates are operated by a gantry crane travelling on tracks over the gate slot. After the gates have been lifted a large pawl on each side is lowered, holding the gate in the raised position so the gantry may move to the next gate to lift

it. This same gantry crane will also be used to operate the regulating gates.

The regulating gates, crest gates and water wheels will allow a flood of about 880,000 second feet to flow from the pond without increasing the elevation over 108.5 feet. A reasonable margin of safety will be noted if this capacity is compared with the greatest flood that has been known to occur in the past century, that of June, 1889, which was coincident with, but not caused

FIG. 10.



by, the Johnstown flood, and which has been estimated as having reached a maximum flow of 750,000 cubic feet per second.

There have been many high flows in the river, but with the exception of one the rise has not been within 175,000 second feet of this high flow. The exception is a flow of 647,000 second feet. It is evident, therefore, that there is ample leeway to safeguard the railroad which operates along the east bank of the Susquehanna River.

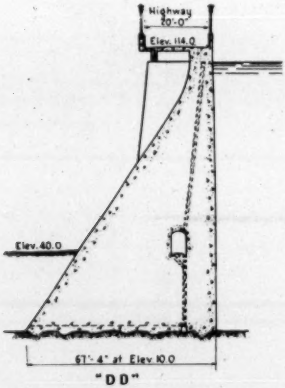
Section *DD* (Fig. 11) is that of the abutment section, which in addition to retaining the water in the pond carries the highway bridge from the land to the crest gate section of the dam.

While it is usually readily understood how the first sections of the cofferdams can be built to start the dam from either shore, it is quite frequently difficult to visualize how the final closure of

the dam can be made and the construction work completed without the water piling up back of the temporary structures and flooding the work. To give a fairly concrete idea of how this will be handled on the Conowingo project, an outline of the various stages of the work has been given in Figs. 12 to 15, inclusive.

Construction is started by building cofferdams from the shore line out into the stream from either side of the river. These cofferdams are shown by light lines. After the cofferdam has

FIG. 11.

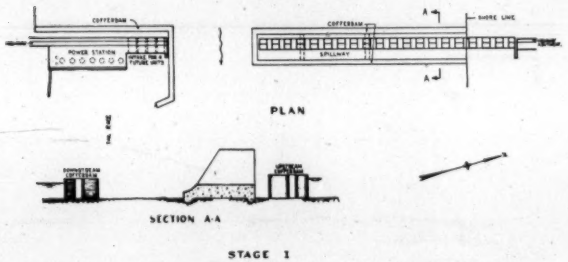


been pumped dry the river bottom is prepared for receiving the concrete mat of the dam structure. Alternate piers are then poured. Section *AA* shows in light lines the high part of the pier which is shown by small squares on the right-hand shore of the plan view, marked Stage I (Fig. 12). The intervening sections on the plan view are shown by the concrete cross-sections. This completes the first stage of the development.

The cofferdams shown in *AA*, Stage I, are then opened to allow water to flow through this section of the dam between the piers that have been raised. After this has been done the cofferdam is extended from the power-plant end as shown in Stage II (Fig. 13). This closes the former opening through which the river passed and allows construction work to be completed in this

section of the river. While work is being done here the power-plant section is being completed and the piers on the Section *BB* are brought to the level of the highway bridge structure. After

FIG. 12.

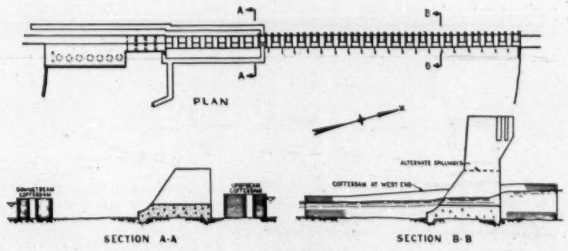


STAGE I

the alternate piers have been placed across the river the gates to the openings for the four future turbines are removed and the river allowed to flow through this section. When all the piers have been completed the highway is then built and traffic diverted from the old Conowingo bridge which will be flooded as the pond elevation is increased.

This arrangement allows the flood waters to freely pass down

FIG. 13.

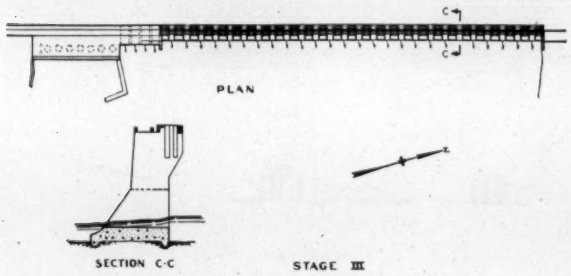


STAGE II

the river. During the low-water period sufficient water will pass through the open sections and the future wheel openings to allow the low sections between the piers to be gradually built up. This

is shown in Stage III (Fig. 14), Section *CC*, and Stage IV (Fig. 15), Section *DD* and Section *EE*, one part of this section always being kept ahead of the remainder so that any flood waters may

FIG. 14.



pass over the low parts of the dam and not interfere with work on the remainder of the dam. When Stage IV is reached it is very easy to fill the unfinished sections between the piers during the low-flow season.

The greatest amount of excavation occurs in the tailrace as is indicated in Fig. 16. It is necessary to excavate over 400,000 cubic yards of rock for the power-house and tailrace. The key

FIG. 15.

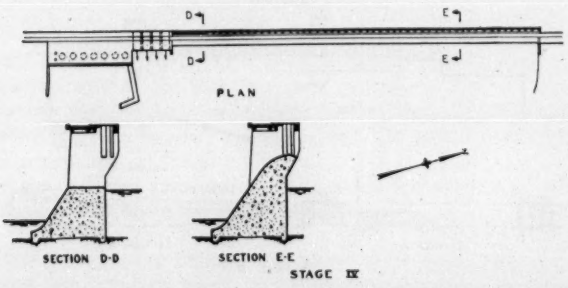


plate (Fig. 17) shows the excavation of the east branch of the tailrace, the west branch being a natural channel requiring practically no excavation. Profiles *AA* and *BB* (Fig. 16) are, respec-

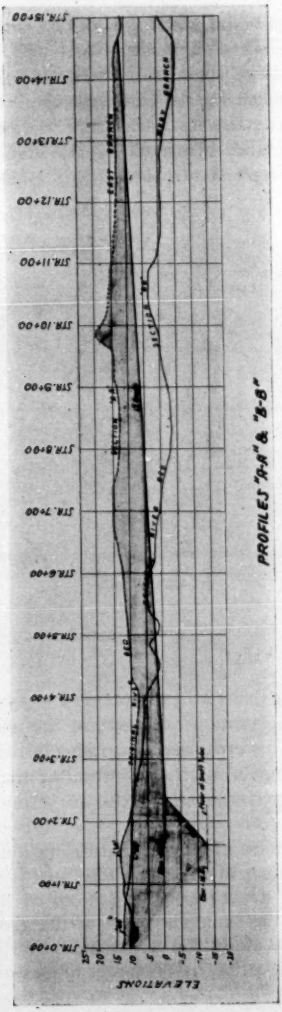
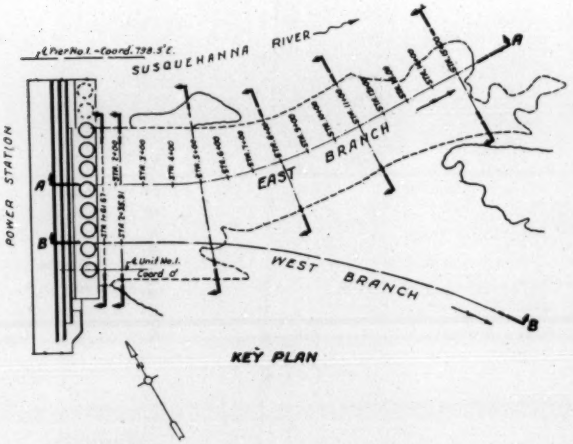


FIG. 16.

tively, for the east and west branches of this tailrace. It will be noted that there is no excavation for the west branch below station 6 + 00. A large amount of rock, however, must be removed from the east branch for the entire distance from the power-house to between coördinates 14 and 15. The east and west branches of the tailrace are separated by Rowland's Island. Station 1 + 61.67 (Fig. 18) shows the tailrace excavation at the down-

FIG. 17.

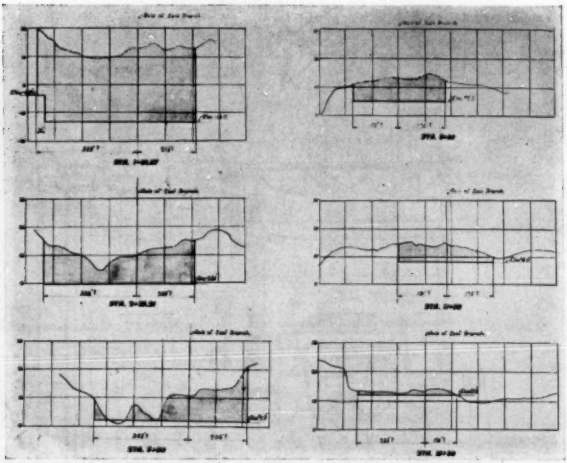


stream end of the draft tubes. Station 2 + 35.91 (Fig. 18) shows the amount of excavation necessary at the end of the steep slope of the tailrace. This cross-section gradually reduces in the quantity of rock to be removed until the bottom of the tailrace approaches the river bed, approximately 1500 feet from the upstream face of the dam.

The cross-section of the generating station through one of the main units is shown in Fig. 19. The dam is used as one side of the power-house structure. The bottom of the intake tunnels to the wheels is at the same elevation as the river bottom. A curtain wall extends along the entire upstream face of the power-house from an elevation of 68.5 feet to elevation 115 feet. This

curtain wall, which is 40 feet below the high-water level, prevents ice from being drawn into the screens and blocking them. Guides are installed in the concrete piers between walls for the trash rake, trash rack and sectional head gates. The sectional head gates are operated by the gantry cranes running on the 20-foot track centres. The trash rack can also be removed with this same gantry. The trash rake is operated by a small movable crane mechanism

FIG. 18.



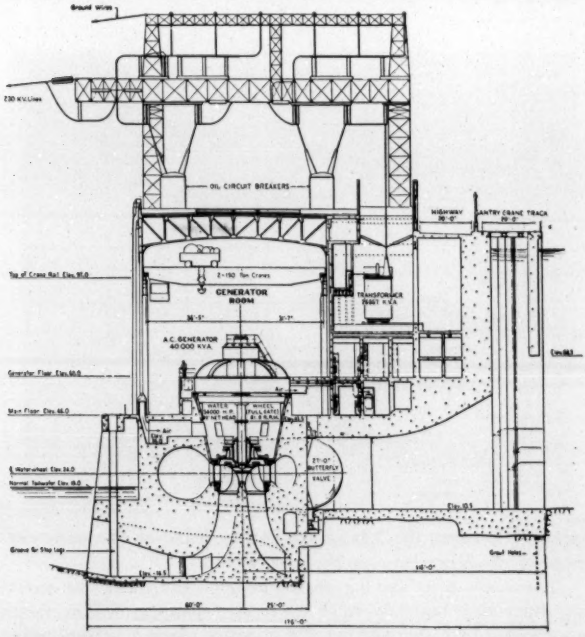
operating between the legs of the gantry crane on the narrower gauge track shown between the gantry tracks.

The water after having passed through the trash rack must pass through a butterfly valve 27 feet in diameter. This valve is supported by a step-bearing and operated about a vertical axis, the operating mechanism consisting of a large cylinder attached by a connection rod to a bell crank on the upper end of the shaft of the butterfly valve. The butterfly valve, after having been closed, is tightly sealed by a piece of large heavy rubber hose imbedded in the stationary seat of the valve and subject to interior pressure. This butterfly valve is used to control the units, stopping and

starting them as desired, so that it is necessary to drop the head gates into place only when repairs must be made on the butterfly valve or the tunnel on the upstream side of it.

Water passes through the regulating gates, which are controlled by a hydraulic governor, to the runner, and thence through

FIG. 19.



a spreading draft tube to the tailrace. Stop logs are placed at the end of the draft tube discharge to permit making any repairs to the draft tube that may be necessary. These stop logs are operated by a small gantry crane on tracks along the downstream face of the power-house.

The water wheel has an output of 54,000 h.p. at full gate

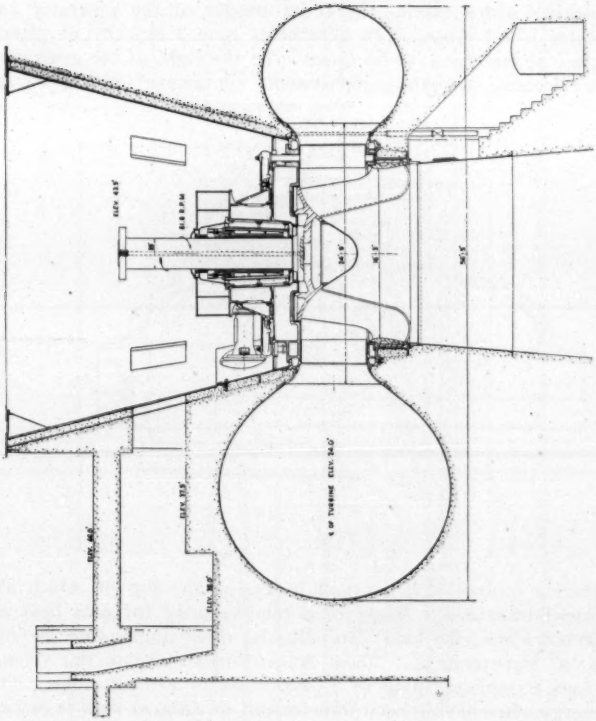
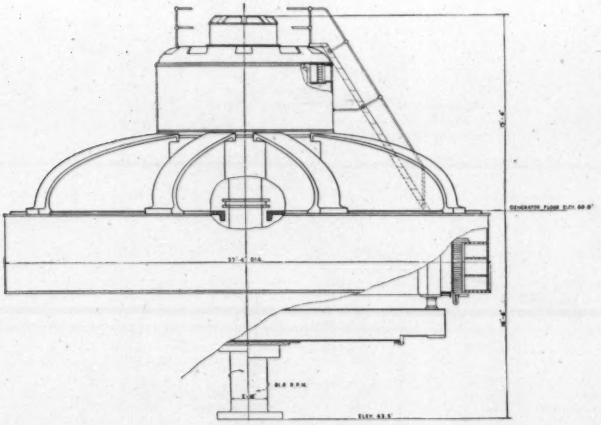


FIG. 20.

with an 89-foot net head and operates at 81.8 r.p.m. This is the largest machine for this speed that has ever been built.

The electric generator is mounted directly above the water wheel, and on the frame of the generator is supported a thrust bearing which carries the entire weight of the generator and water wheel rotor. The generators have a capacity of 36,000 k.w., 40,000 k.v.a. at 60 cycles. To the right of the generators are located concrete compartments containing the low-voltage

FIG. 21.



electric control switches and buses, on the top of which are placed transformer banks of a total capacity for each bank of 80,000 k.v.a., the bank consisting of three single-phase 26,667-k.v.a. transformers. These transformers increase the voltage from a nominal value of 13,200 volts to 220,000 volts. The energy after having been transformed to 220,000 volts is carried vertically to the bus structure on the roof where the oil switches controlling the transformer banks and the outgoing lines are located. The areaway to the right of the transformer banks is used for moving the transformers out of the station in event of their failure. These transformers can be wheeled onto a car running on rails in the areaway and moved to the end of the

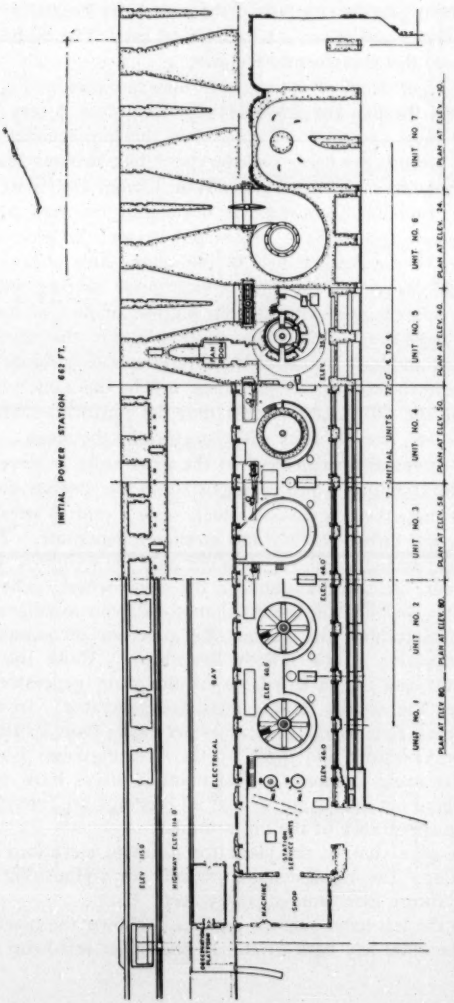

INITIAL POWER STATION 660 FT.
7-INITIAL UNITS 72'-0" C. TO C.
UNIT NO. 1
UNIT NO. 2
UNIT NO. 3
UNIT NO. 4
UNIT NO. 5
UNIT NO. 6
UNIT NO. 7
PLAN AT ELEV. 90
PLAN AT ELEV. 80
PLAN AT ELEV. 58
PLAN AT ELEV. 50
PLAN AT ELEV. 40
PLAN AT ELEV. 34
PLAN AT ELEV. -10
ELECTRICAL BAY
ELEV. 115'
HIGHWAY ELEV. 114'-0"
MACHINE SHOP
STATION SERVICE UNITS
ELEV. 66'-6"
ELEV. 46'-6"
ELEV. 46'-6"

FIG. 22.

generating station at which point a crane is located to pick up a transformer and lower it to a railroad car. The highway is carried over this transformer runway.

A larger detail of the water turbine is shown in Fig. 20. The diameter through the scroll of 56.5 feet gives a very good idea of the large size of this turbine. In the initial installation four of the turbines are being built by the Allis-Chalmers Manufacturing Company and three by the Wm. Cramp and Sons Ship and Engine Building Company. In developing this new machine the two manufacturers have coöperated to such an extent that the runners of the turbine will be interchangeable although not of identical design and the lignum-vitæ guide bearing will be completely interchangeable, thus reducing the amount of spare equipment necessary. While the governors for the units will be designed and built by the manufacturer whose turbines they control, nevertheless, the oil pressures will be the same on all units so that the oil supply system may be uniform. The pumps, motors, etc., for all units will therefore be the same.

The general arrangement of the generators is shown in Fig. 21. The armature, which is supported on the concrete foundation, carries supporting beams on which rests a central structure containing the thrust bearing and auxiliary generator. The thrust bearing, running in oil, supports not only the weight of the generator rotor, but also the runner of the water wheel. The auxiliary generator supplies the essential motor-driven auxiliaries of the individual turbine, the exciter, the governor oil pumps and the fans supplying air to cool the generator. Above the auxiliary generator and on an extension of the main generator shaft is mounted the exciter for the auxiliary generator. In the initial installation four of the generators are being built by the General Electric Company and three by the Westinghouse Electric and Manufacturing Company. The manufacturers have coöperated in working out the design so that all bearings are interchangeable and the appearance of the units similar.

The plan view of the plant for different elevations is shown in Fig. 22. The initial installation calls for a plant 662 feet long with a future extension of 288.5 feet.

On the left-hand side of Fig. 22 is shown the machine shop with the office bay back of it. In the upper left-hand corner at

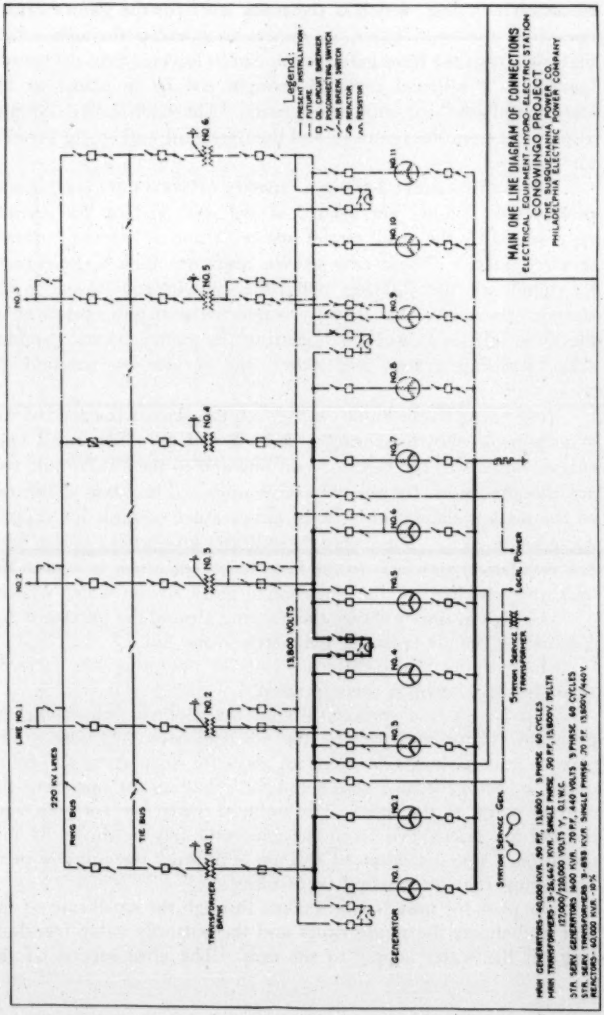

MAIN ONE LINE DIAGRAM OF CONNECTIONS
ELECTRICAL EQUIPMENT - HYDRO-ELECTRIC STATION
CONOWINGO PROJECT
THE SUSQUEHANNA POWER CO.
PHILADELPHIA ELECTRIC POWER COMPANY
Legend:
PRESENT INSTALLATION
FUTURE
OIL CIRCUIT BREAKER
DISCONNECTING SWITCH
NON GREEN SWITCH
REACTOR
POTENTIAL TRANSFORMER
220 KV LINES
MAIN BUS
TIE BUS
LINE NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
NO. 6
TRANSFORMER BANK NO. 1
GENERATOR
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
NO. 6
NO. 7
NO. 8
NO. 9
NO. 10
NO. 11
13,800 VOLTS
STATION SERVICE GEN.
STATION SERVICE TRANSFORMER
LOCAL POWER
MAIN GENERATORS - 40,000 KVA. 90 P.F., 13,800 V., 3 PHASE, 60 CYCLES
MAIN TRANSFORMERS - 3-26,667 KVA. SINGLE PHASE, 90 P.F., 13,800 V. DELTA
(231,000/230,000 VOLTS Y, 0.1 W.C.
STA. SERV. TRANSFORMERS - 1800 KVA., 70 P.F., 4160 VOLTS, 3 PHASE, 60 CYCLES
STA. SERV. GENERATOR - 1,688 KVA., 70 P.F., 4160 VOLTS, 3 PHASE, 60 CYCLES
REACTORS - 60,000 KVA. - 10%
1,688 KVA., SINGLE PHASE, 70 P.F., 13,800/4160 V.

FIG. 23.

elevation 115 feet, which is the track level for the gantry cranes operating the head gates, is shown an opening through which material from the head gate section can be lowered into the tunnel, loaded on a railroad car and brought out to be placed in the station and machine shop for repairs. The electric bay occupies a space between the roadway and the upstream wall of the generator room.

Two station units, having a capacity of 1900 h.p., 1600 k.v.a., each at 360 r.p.m., are located at the west end of the station, represented by the small circles marked 1 and 2, lettered "station service units." These two service units are each large enough to supply all the lighting and other power equipment in the station other than that directly connected with the operation of the main units. Power for operating the gantry cranes, machine shop, building cranes and other like service, is supplied by these units.

Proceeding to the right on Fig. 22, the plan of the tops of the generators is shown, marked "units 1 and 2." The small egg-shaped objects to the right of unit one and to the left of unit two are the governors for the respective units. The circle at the top of the rectangular opening is the air pressure oil tank for supplying governor oil. The rectangle indicates an opening in the floor for ventilation and light to the floor below on which is located the operating mechanism for the control gates of the water wheels.

The plan at unit 3 shows the housing around the generator for conducting the air from the generator to the fan.

The cylinder and connecting rod for operating the butterfly valve is also shown at this elevation.

Unit No. 4 is a section through the concrete supporting the generator stator and part of the air admission enclosure. The plan at unit 5 shows the concrete piers for supporting the foundation of the generator stator and the cylinders for operating the control gates of the unit. The induced draft fan for removing the hot air discharged from the generator is also shown at this elevation. The discharge of this air is through the concrete piers separating the water wheel penstocks.

The plan for unit No. 6 is taken through the scroll case of the unit and shows the guide vanes and the butterfly valve for shutting off the water supply to the unit. The cross-section of the

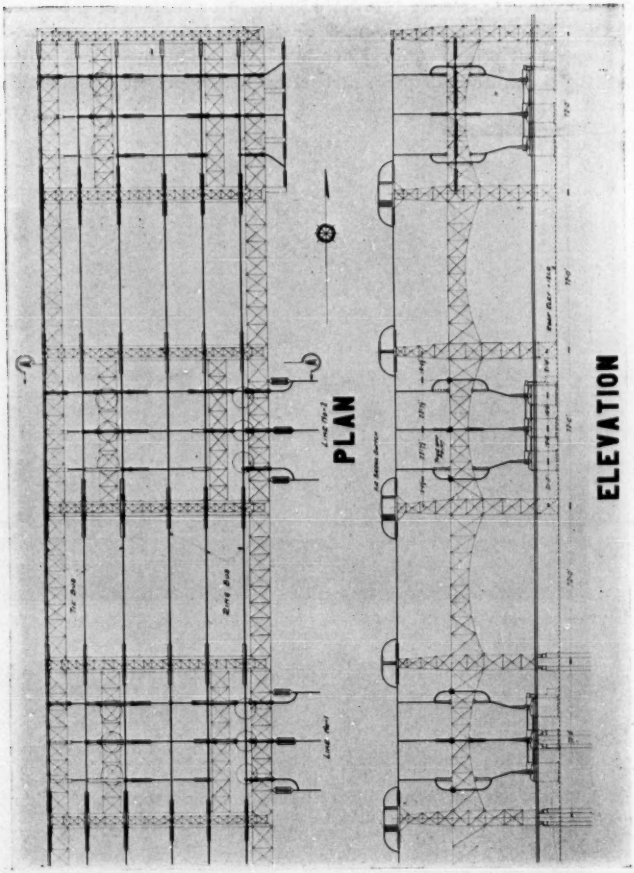


FIG. 24.

plan at unit No. 7 shows the draft tube with the vanes supporting the concrete structure forming the exterior surface of the cone.

The single line diagram of the 13,200-V. and 220,000-V. switching equipment is shown in Fig. 23. The solid lines indicate the equipment that will be installed in the present development;

FIG. 25.

View from west shore, looking east into power plant and tailrace cofferdam, with east cofferdam in the left background. August, 1926.

the dotted lines indicate the arrangement of connections for equipment in the final installation.

It will be noted that in the original installation the station is divided into low-voltage bus sections with two main generating units supplying each section. Arrangements have been made so that bus sections 2 and 3 may be directly tied together. This is for increasing the flexibility of operating the station at low load periods.

It will be noted that as more units are added to the station, reactors may be installed in these bus ties so as to limit the possible short circuits on the 13,200-V. bus. In no case will more

FIG. 26.

Same view as Fig. 25, taken in December, 1926.

FIG. 27.

Within west cofferdam looking toward west shore.

than four machines be tied together on a bus section without an intervening reactor.

To each of the 13,200-V. generator sections an 80,000-k.v.a. transformer bank is solidly connected with arrangements to tie all the banks in parallel on the high-tension bus through oil switches. The two outgoing transmission lines are connected to

FIG. 28.

Appearance of river bottom in west shore cofferdam at the beginning of construction work.

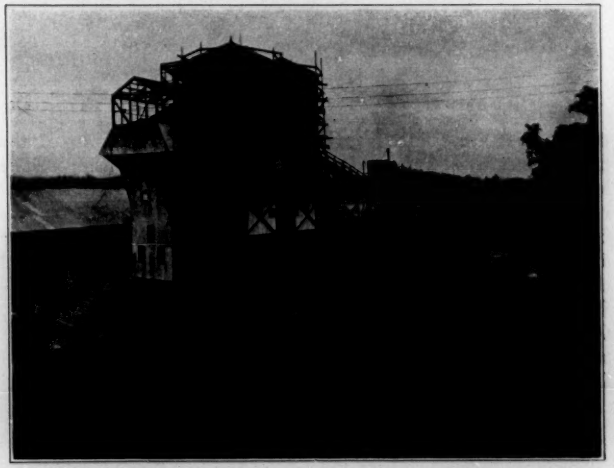
this bus by means of automatic oil switches, but in the event of complete failure of one of these oil switches either line may be attached to the ring bus which is fed directly from the tie bus, the ring bus being supplied either by an automatic oil switch or an air-break switch. The transformers are connected delta on the low-voltage side and *Y* on the high-voltage side with the neutral point of the *Y* solidly grounded.

It will be recalled that auxiliary generators were shown in Fig. 22 for supplying those auxiliaries not directly involved in the operation of the individual generator. This auxiliary supply is further supplemented by a transformer connected to two

FIG. 29.

West end of abutment wall.

FIG. 30.



Concrete mixing plant for west shore construction work.

13,200-V. bus sections through oil switches so that maximum flexibility and efficiency of the power supply to the plant can be obtained.

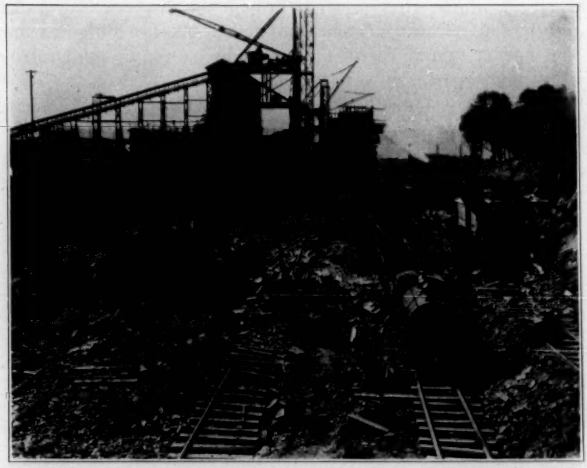
A plan view and elevation of the high-tension substation on the roof of the power-house is given in Fig. 24. The cross-section of the plant is shown in Fig. 19. In Fig. 10 the main leads of the

FIG. 31.

East shore looking west into east shore cofferdam at the beginning of work in the river bed.

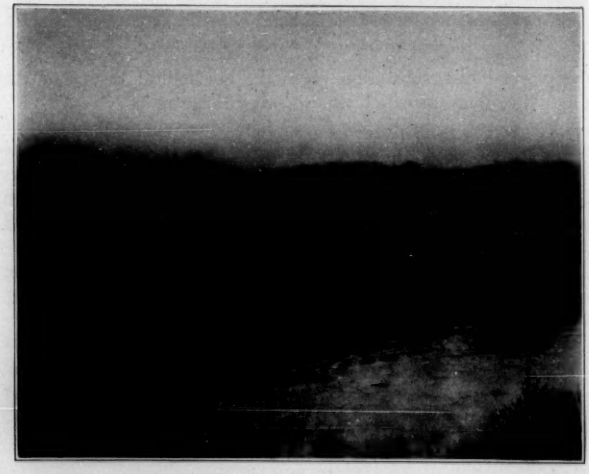
transformer are guided above the 220-terminal bushing of the transformer by a string of 14-disc insulators in tension. The lead then passes to a post type insulator supported from the steel roof structure and from this point to the terminal of a disconnecting switch. The outside insulators of this disconnecting switch are stationary posts. The two inside insulators move inward and disconnect the leads that are attached to the oil switch terminals from the transformer lead and from the lead going to the bus. On the left-hand side of the disconnecting switch the lead passes to a bus lead supported between two sets of strain insulators and from this bus lead upward over a post type insulator to the main

FIG. 32.



Concrete mixing plant and material distributing system for east shore construction work,

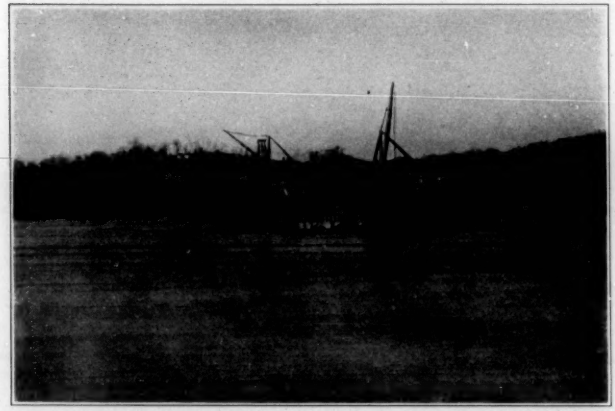
FIG. 33.



Looking toward east cofferdam from west shore of river.

bus. From the left-hand side of this same bus lead a connection is taken off which, after passing through the disconnecting switch and the line oil switch, is attached to the 220-k.v. outgoing line. The line is tapped to an air-break disconnecting switch from which a lead passes upward to the ring bus located on the top of the left-hand section of the steel work structure. This view of

FIG. 34.



Looking toward east cofferdam from west cofferdam.

the power-house substation gives the mechanical layout of the single line diagram which was shown in Fig. 23.

The elevation in Fig. 24 shows the connection arrangement of both the main and the ring bus. The line is taken out in the same bay in which the transformer leads are connected; the intervening bay being vacant. A sectionalizing disconnecting switch is in the main bus and shown on the right-hand column of each bay.

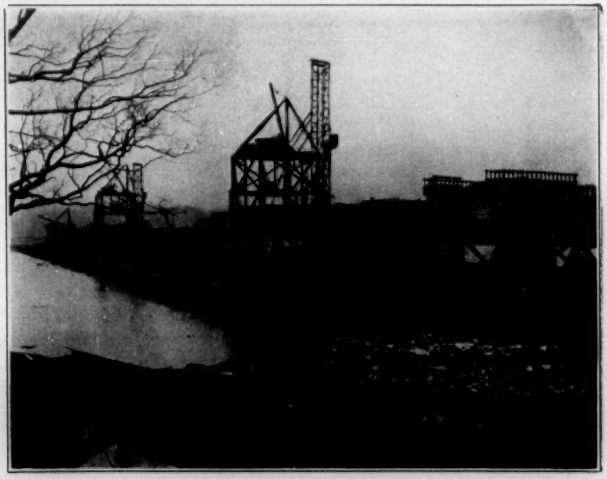
Referring to the plan view of Fig. 24, it will be seen that the tie bus only has the sectionalizing air-breaks in it, while the ring bus is a solid bus for its entire length.

A tie oil switch for connecting the ring bus and the tie bus is shown in the bay at the extreme right of the steel structure. It will be noted that the entire substation is symmetrical in layout

FIG. 35.

Looking toward shore from west end of east construction bridge.

FIG. 36.



Looking toward west shore from south side of east construction bridge.

so that all disconnecting and oil switches have a definite relation in each one of the bays.

The heavy equipment on the roof can be moved on trucks running over rails laid parallel with the cross-section of the plant to a longitudinal railway track and transferred to the end of the generating station, at which point it can again be moved on transverse tracks to an opening in line with the location of the transformers below. From here it can be lowered by a stationary crane to the transformer bank elevation and removed in the same manner as the transformers.

Figs. 25 to 32 are shown to indicate the progress of this work as well as some of the construction equipment necessary and some of the obstacles that must be overcome.

Figs. 33 to 36 show the conditions at the project during the high flow of November 17, 1926, which reached 350,000 second feet.

THE DISTILLATION OF PETROLEUM FOR THE MANUFACTURE OF LUBRICATING OILS.*

BY

WILLIAM F. PARISH.

Consulting Lubrication Engineer.

ONE million years ago, near the present site of Los Angeles, Calif., there were chimneys or openings formed by blowouts of gas from the underground petroleum reservoirs. In these chim-

FIG. 1.

The old Rancho-la-Brea (Ranch of the Tar Pools), property of Major Henry Hancock, surrounded by trees and clumps of cactus, the "Brown pool" and pits (9, 10, 11, 12) in the foreground, oil-pumping wells above the oil-bearing strata in the middle distance, and the Coast Range beyond. In this large pool was secured, shortly after the discovery, the first Los Angeles High School collection, also skeletons of the sloth (Mylodon), and a complete mastodon skeleton. Courtesy of the Museum of History, Science and Art, Los Angeles.

neys the asphalt flowed to the surface and, in time, partly dried as the lighter parts volatilized. Dust swept over this sticky asphalt and water settled in its depressions. This water, during the seasons of drought, attracted the animals of the region. The pools became effective animal traps, the captured beasts acting as live bait for other mammals, and birds of prey, gathering for the

* Presented at a meeting held Thursday, November 4, 1926.

feast, were in turn themselves entrapped. As the struggling creatures sank into the sticky petroleum, and as the tissues of their bodies decomposed, the asphaltic material settled into the cavities of the skulls and into the pores of the bones, effectively preserving them for all time.

The bones from these pools attracted the attention of scientists in 1906, who found [1] that they were not modern bones but those that had belonged to animals now extinct. The explorations that have taken place since have laid bare the most astonishing findings of the skeletons of prehistoric animals and birds ever discovered.

FIG. 2.

The Tar Pool Death Cycle. Reproduction from the Rancho-la-Brea mural drawn by Charles R. Knight under the direction of Henry Fairfield Osborn. This mural is on the southeast wall of the Hall of the Age of Man, American Museum of Natural History, New York City, through whose courtesy this cut is reproduced.

The entire bird and mammal fauna of Southern California at the time these asphalt pools were actively capturing their prey are represented.[2]

A recent summary [3] included twenty-nine species of the greater mammals, twenty-one species now being extinct. Among the last are the lion, the sabre-toothed tiger, a wolf of large proportions, the small and the giant sloths, the camel, the ancient elephants, the American mastodon and the imperial southern mammoth. The skeletons of seventeen elephants were found in

[1] See notes on the Pleistocene Fossils obtained from the Rancho-la-Brea, by L. R. Wyman, 1918.

[2] See "Mammals and Birds of the California Tar Pools," by Henry Fairfield Osborn, "Natural History," 6, 1925.

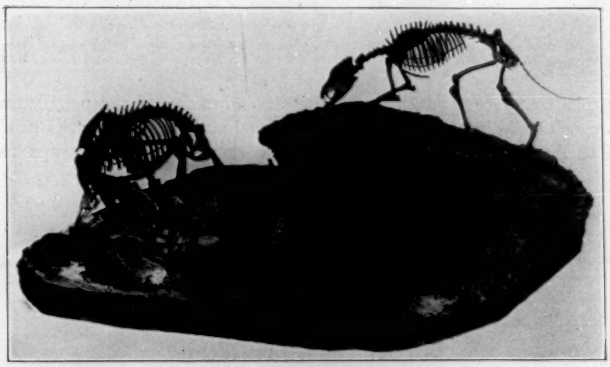
[3] See the "Pleistocene Megalonychinæ and Mylodontadæ of Rancho-la-Brea," by Chester Stock, 1915.

one pool, along with a great quantity of the bones of other animals. This pool was 35 feet deep and 15 × 25 feet in dimensions at the top, and was too small to contain the huge bodies of these seventeen elephants all at one time. This indicates that the traps were active over a long period of time. The skeletons of more than 10,000 birds and more than 5000 mammals have been found.

REMOTE ANTIQUITY OF PETROLEUM FORMATION.

The presence of the imperial southern mammoth (Archidiskodon Imperator) places the pools as in existence before the

FIG. 3.



Made with skeletons from the Rancho-la-Brea Tar Pools, showing the sabre-tooth tiger to the left, extinct wolf to the right and ground sloths in the foreground. Courtesy of the American Museum of Natural History.

Pleistocene Age, this elephant belonging only to this period. Therefore, petroleum in approximately its present form and consistency was on the earth's surface before the time of these early animals. Dr. Chester A. Reeds, of the American Museum of Natural History, procured samples of asphaltic deposits from the inside of the skull of one of the extinct mastodons, which has been recently removed from the elephant pit. These deposits were examined in the research laboratory of the Zieley Processes, and will be reported later in a memoir written by Doctor Reeds.[A] Asphalt extracted from the deposit is basically the same as the asphalt found in other parts of the chimney, representing the

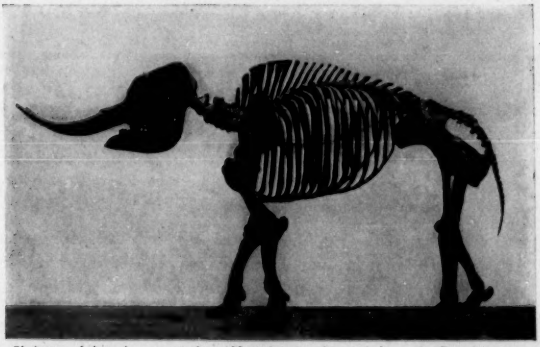
petroleum of to-day, though the sample from the skull had undergone somewhat greater decomposition. The absence of great change between the ancient sample from the skull and California

FIG. 4.

Outline restoration of the American mastodon of the Rancho-la-Brea (1/75 natural size). Drawn by L. M. Sterling. Courtesy of the American Museum of Natural History, New York City.

asphalt of recent years shows the stable quality of the petroleum deposits. When the Dawn Man arrived and visited what is now Los Angeles, he could have used the services of these traps to

FIG. 5.

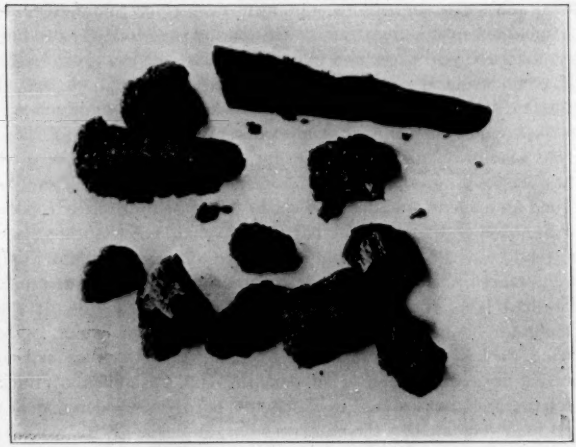


Skeleton of American mastodon (*Mastodon americanum*) from the Rancho-la-Brea, as mounted in the Museum of History, Science and Art, Los Angeles. Photograph (1/50 natural size) reproduced through courtesy of that museum.

help provision the family. He easily could have made use of the petroleum pitch for a number of things of a very simple nature, as did the early men in other parts of the world.

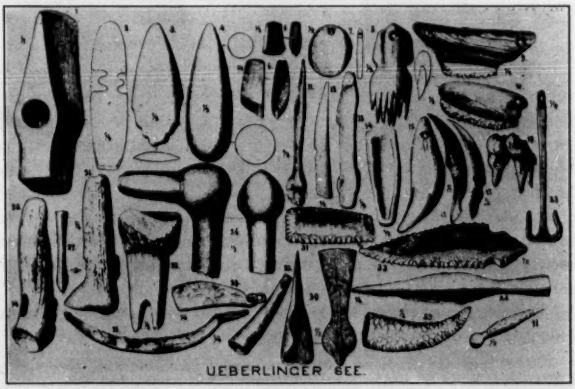
In the lake dwellings of Switzerland and of Southern Ger-

FIG. 6.



Photograph showing pieces of wood, bone and asphalt removed from the mastodon's skull, the skeleton having been taken from the tar pool of the Rancho-la-Brea near Los Angeles, Calif.

FIG. 7.



Stone Age implements where, according to Doctor Keller,[4] asphalt was used in cementing the flint flakes to wooden handles as shown in Nos. 9 and 10, and to bone handles as shown in 20, 21 and 22. Print taken from Doctor Keller's book published in 1866.

many, as well as of other parts of the old world, there have been many relics found of man's equipment during the Stone Age and before metals were discovered. This period is estimated as ending about 10,000 years ago, and undoubtedly lasted for a great length of time during which man attained a relatively high degree of culture. His implements were all made of stone, flints, bone, horn, wood or earthenware, and examples have been found where these lake dwellers lived.[4] Doctor Keller's first discovery of these deposits was at Meiln, Switzerland, in 1855. There he found an ancient saw, made of sharp flakes of flint set in a block of fir wood and fastened by hardened asphalt. At another place he found pieces of broken pottery, where the vessel evidently had been cracked and mended by petroleum pitch, mixed with ashes, that had been run through holes drilled on each side of the fracture. From other deposits various other implements were found, such as chisels of flint with handles of thick asphalt to prevent injury to the user; a drinking cup, fashioned of thick asphalt; and many tools in which the horn or wooden handles had been cemented to the flint or stone implement with asphalt. This is the earliest record showing that petroleum has been of actual material aid to man, probably to as great an extent, in proportion to his needs and equipment, as it is to us to-day with our greater necessities.

EARLY USE OF PETROLEUM SUBSTANCES.

The petroleum substances referred to under the names of bitumen, asphalt, malta, naphtha and the like, have been known and used from the earliest times. Practically all of our modern petroleum nomenclature is of actual Greek and Roman origin. These people distinguished three related substances: (*a*) The Greek *asphalton* and the Roman *bitumen* for the hard materials; (*b*) the Greek *pissasphaltos* and the Roman *maltha* for the viscous and pitchy kinds; and (*c*) occasionally the Greek and the Roman *naptha* for *petroleum* proper; though it is frequently referred to as liquid bitumen or liquid asphaltos.

Towns, rivers and districts have been named after petroleum, which indicates its early occurrence.[5] There are several Pitch-

[4] See "Lake Dwellings of Switzerland and Other Parts of Europe," by Ferdinand Keller, 1866.

[5] See "Oil Field Development," by A. Beeby Thompson, 1916, p. 2.

fords in England, doubtless owing their name to the occurrence of petroleum pitch or oil. Brea is the Spanish name for pitch. La Brea is the name of the ranch near Los Angeles where the skeletons of the extinct animals have been found. This place was named by the earliest Spanish settlers. In Burma, the word Yenang (earth oil) prefixed to other words has been applied to

FIG. 8.

Single still of the year 1500 A.D.—after H. Brunschwyg.

localities where petroleum was first found and where there are now large developments. In Russia, such places as Neftiano (neft-oil) are met with. Likewise, in Germany, Pechelbroon (pitch spring); on the Red Sea, Gab-el-Zeit (head of oil); and in Algeria, Ain Zeft (oil well) are in use, while in Galatia, Rumania and Mexico, the native names of Ropa, Pacura and Chapopote all signify petroleum in one form or another. In Persia, Kir (pitch) frequently is prefixed to the names of places indicating

the existence of petroleum, such as Kirman, all of which is very significant in indicating antiquity.

Professor Fessenden[6] suggests that the "Egyptian Book of the Dead" embodies references to the Caucasus region, which begins in Northern Persia. "The most fertile paradise in which was a pool of fire" is now supposed to be the valley of the river

FIG. 9.

Fire still with four retorts, 1500 A.D.—after H. Brunschwyg.

Iora in which is a great oil spring in a district noted for fertility and beauty.

Bitumen was used by the Egyptians for embalming prior to the year 5000 B.C., the term "mummy" arising from the Persian word for bitumen, which is *mumiai*. Bitumen for this particular purpose was used extensively and for many thousands of years; it was, therefore, a well-established and standardized article of commerce. Herodotus (484–424 B.C.) indicates the ancient method of manufacture when he refers to a well in Ardwricca, about forty miles from ancient Susa in Persia as follows:

> From this well they get bitumen, salt and oil, procuring it in a way that I will now describe; they draw with a swipe, and instead of a bucket they

[6] See "The Dawn of Civilization," by Sir Flinders Petrie, *The Forum*, Oct., 1926, p. 535.

make use of the half of a wine skin; with this the man dips and, after drawing, pours the liquid into a reservoir wherefrom it passes into another and there takes three different shapes. The salt and bitumen forthwith collect and harden, while the oil is drawn off into casks. It is called by the Persians rhadiance, is black and has an unpleasant smell.

Christophoro Encelius, writing in 1551, has furnished us with a practical bibliography on the subject in a chapter on bitu-

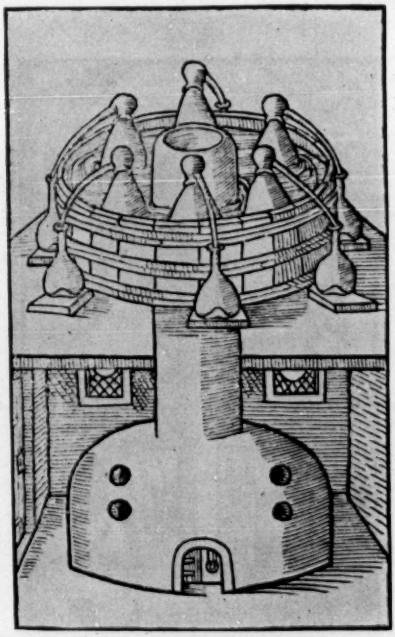
FIG. 10.

Two goose-neck stills with worm condenser and receiving flasks. Shown by Philippo Ulstadio, 1525 A.D.

men and one on naphtha, in his book on the "Origin, Variety and Nature of Metals, Minerals, Precious Stones, Etc." He tells the places where petroleum was found by the ancients, the manner of its preparation and the fact that it was brought into the markets by the "Agyrtæ," those forerunners of the modern oil man. Encelius gives much of interest and value to the student

and, as the book is exceedingly rare, a translation is affixed to this paper as a reference.[B] Georgius Agricola, in his famous work, "De Re Metallica," [7] published in 1556, gives a general summary of the ancient method of the manufacture of petroleum and shows

FIG. 11.



Fire still with six retorts, shown by Philippo Ulstadio in his "Secrets of Nature," published in 1525 A.D.

how it was prepared in his day, accompanied by an unique copper plate illustration. He says:

Bitumen is made from bituminous waters, from liquid bitumen and from mixtures of bitumen substances. The water, bituminous as well as salty, at

[7] See Hoover's English translation of Agricola, London, 1912, book XII, p. 581.

Babylon, as Pliny (79–23 B.C.) writes, was taken from the wells to the salt works and there heated by the great heat of the sun, and condensed partly into liquid bitumen and partly into salt. The bitumen, being lighter, floats on top, while the salt, being heavier, sinks to the bottom. Liquid bitumen, if there is much floating on springs, streams and rivers, is drawn in buckets or other vessels; but when there is little, it is collected with goose wings, pieces of linen, shreds of reeds and other things to which it easily adheres, and it is boiled in large brass or iron pots by fire and condensed. This bitumen is put to diverse uses; some mix pitch with the liquid, others old cart grease, in order to temper its viscosity, these, however long they are boiled in the pots, cannot be made hard. The mixtures containing bitumen are also treated in the same manner as those containing sulphur, in pots having a hole in the bottom, and it is rare that such bitumen is not highly esteemed.

Agricola's mention of cart grease, which was of animal or of vegetable origin in those days, being mixed with petroleum to temper its viscosity, is without doubt the first reference of the mineral oils being used for compounding. During the centuries up to our time all lubrication was carried on with the animal and vegetable oils and fats, as they were easily obtained, were always uniform in consistency and, in fact, were made by the user himself or by one of his townsmen. There can be no doubt that the more liquid forms of petroleum were occasionally used as lubricants, or for tempering or covering metal for protective purposes against corrosion.

Primitive man has, at times, been curious and, in general, very observing. Roughly prepared and probably partly burned, the appearances of rendered tallow and of the viscous petroleums would be similar, and the use of one would surely suggest the use of the other. The petroleums were used by early man for such a wide variety of purposes that we can assume that they were used also for lubrication whenever the material was available and was not too costly.

LATER METHODS OF PROCEDURE.

The alchemists of the middle ages used a variety of stills, none of them made particularly for the purpose of distilling petroleum, but suitable for all liquids that needed to be so treated. Hieronymus Brunschwyg (Herman Brunswich) published the first edition of his book of "Distillation" in 1500 A.D. The English edition by Lawrence Andrews (1527) says: "A VERTUOSE BOKE OF DISTYLLACYON with the Fygures of the Styllatoryes, first made and compyled by the thryte Yeres Study

and Labour of the most conynge and famous Master of Phisyke." This book, which is exceedingly rare, shows several original forms of stills which undoubtedly represent apparatus that had been in use for many hundreds of years. Two forms of still are shown in which the retorts are heated by direct fire, and in which the goose-necked flasks are pyramid shaped, set into the top of the

FIG. 12.

A—BITUMINOUS SPRING. B—BUCKET. C—POT. D—LID.

Collecting petroleum from a spring and "boiling it in a brass or iron pot" as shown by Georgius Agricola, in his "De Re Metallica," 1556 A.D.

furnace. Neither of these stills has separate condensers and, if petroleum was being distilled, condensation would have to take place in the top of the retort and along the goose-neck.

Philippo Ulstadio, in his "Secrets of Nature," published in 1525, shows a most interesting combination still that contained every element necessary for distilling petroleum. The goose-necked flasks are connected to worm condensers that are in a vertical water tower and, after leaving the condensers, the distillate runs into the receiving flasks. The general form of all the apparatus is quite like that which is employed in our laboratories to-day, although, if we believe the old prints, our modern chemists

have certainly lost the art of holding these highly heated stills in their bare hands.

In his work on "Philosophical Furnaces," printed in 1651, John Rudolph Glauber shows the general form of iron stills for liquids that are not apt to cause corrosion. He suggests new forms of condensers, and this apparatus was the one that was used for securing the necessary "cuts" from petroleum for medical and other purposes. The medicinal properties of petroleum were early recognized. The early Indians in our own country attributed the highest medicinal virtues to petroleum, which they skimmed from streams and prepared by boiling. Seneca oil, so called by its having been collected and used in their religious ceremonies by a tribe of American Indians, was traded in considerably among the early white settlers. In fact, petroleum, as such, was referred to as Seneca oil for many years.

The 1828 *Transactions of The Franklin Institute* contain a letter, that can be taken as a review of the time, showing that Seneca oil was used for medicinal purposes, but the writer has a vision that it had other uses as well, as to its future use, that has been more than fulfilled. [8]

FIRST LARGE-SCALE COMMERCIALIZATION.

The preparation of pitch and oil out of shale and coal was recorded very early in the British patent office, Patent No. 214 having been granted to John Becher in 1681 for a "new way to make pitch and tarre out of pit coal." Another patent, granted to Martin Eele in 1694, was for a "way to make great quantities of pitch, tarre and oyle out of a sort of stone of which there is a sufficient plenty." To Talbot Edwards, in 1716, was also granted a patent for making "pitch, tarre and oyle by fire only."

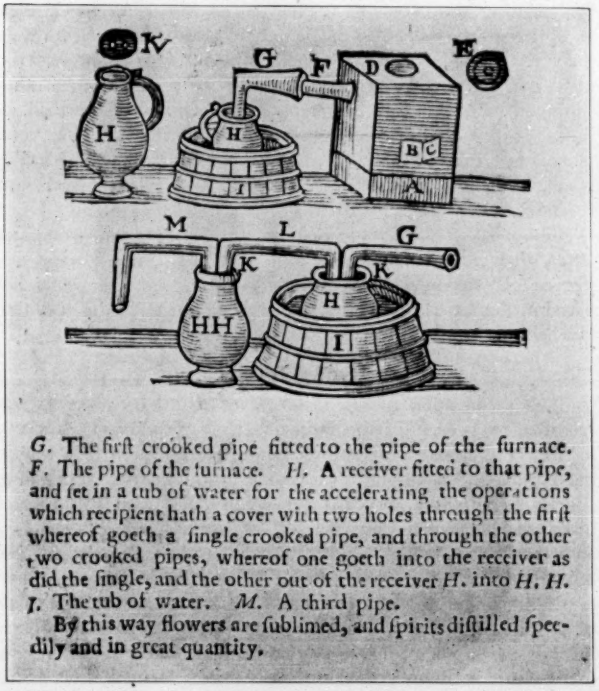
Until James Young took out British patents in 1850, little of a practical nature was accomplished. To Doctor Young belongs the honor of having demonstrated clearly the value and method of distilling petroleums and shale oils on a commercial basis. He thoroughly understood and originated the general art of refining by destructive distillation, his patent being one of the milestones in the industry. His patent reveals a process he had found necessary in handling commercial distillates on a large

[8] See *Transactions of The Franklin Institute*, 5, p. 36.

scale, and this general method has prevailed to this day. The method covers burning oils and lubricants. The production of the lubricants is described as follows:

The crude oil so obtained may be purified by heating it to 150 deg. Fahr., when water and undissolved impurities will separate from it. The clear oil

FIG. 13.



G. The firſt crooked pipe fitted to the pipe of the furnace. *F.* The pipe of the furnace. *H.* A receiver fitted to that pipe, and ſet in a tub of water for the accelerating the operations which recipient hath a cover with two holes through the firſt whereof goeth a ſingle crooked pipe, and through the other two crooked pipes, whereof one goeth into the receiver as did the ſingle, and the other out of the receiver *H.* into *H. H. I.* The tub of water. *M.* A third pipe.

By this way flowers are ſublimed, and ſpirits diſtilled ſpeedily and in great quantity.

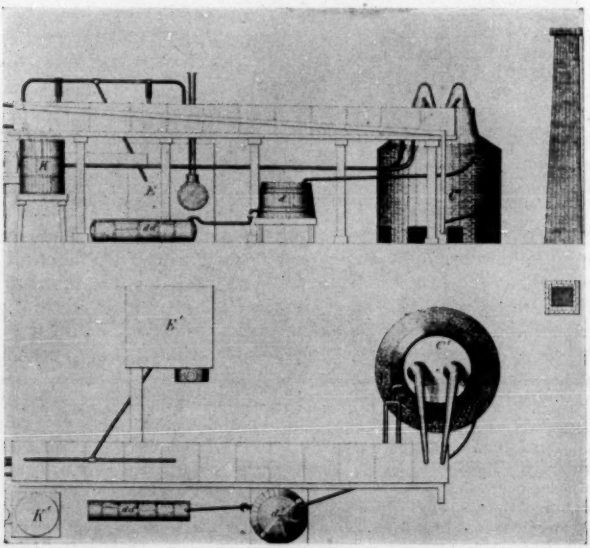
Still with special form of condenser after John Rudolph Glauber, Amsterdam, 1651 A.D.

should then be distilled and condensed, then treated with oil of vitriol and allowed to settle, the supernatant oil being drawn off and agitated with caustic soda. From this a product more volatile than paraffin may be obtained by adding water and again distilling. The clear and transparent fluid so obtained may be burned as an illuminant. The oil left in the still is to be carefully

separated from water and again stirred with oil of vitriol and settled. The supernatant oil is then drawn off and agitated with chalk ground up with water. This oil is kept for a week at a temperature of 100 deg. Fahr., depositing its impurities, and is then fit for a lubricant, either by itself or mixed with animal or vegetable oils, or may be used for illumination.

Doctor Young built a plant in Scotland first designed to use

FIG. 14.



The Franklin Oil Works near Philadelphia in 1871. From a paper by Prop. Edward Parrish in *Transactions of The Franklin Institute*, Vol. 91. (*c*) Still of 19,000 gallon capacity. (*d*) Tub for condenser coils. (*dd*) Run-down tank for lubricant.

crude petroleum, but after this supply gave out the plant was converted to use shale, and the industry continues to the present day. Many Americans took licenses under Young's patent and, in 1859, there were fifty-three companies in this country in active operation producing "rock oil" from shale and coal. At this time Colonel Edwin L. Drake was sent to Oil Creek, Penna., by one of these companies, and "struck oil" after boring to a depth of 68 to 70 feet. Rapid development of this oil-producing field

followed; most of the companies operating under Young's patent converted their plants from coal to crude petroleum production, and the great American oil industry was born.

LATER DEVELOPMENT.

In 1871, Prof. Edward Parrish made a report to The Franklin Institute[9] after having visited one of these early oil refineries, operating in the neighborhood of Philadelphia. The old goose-neck batch-still used by Young was the form selected. This was of 19,000 gallon capacity, was made of wrought iron, was somewhat drum shaped and had two goose-necks for conducting the more volatile vapors away as soon as formed. A pipe was connected lower down in the still, at a point where a ledge extended around the inside and into which, toward the end of the process, the heavier, cracked distillates drained. This refinery was mainly for the production of the burning oils, and gasoline was a troublesome by-product, but could be burned under the still. The lubricating oils were not of enough importance to merit a description except that the heavier distillates were used for the lubricants. The nature of these distillates and the method of their preparation can best be described by another rare classic, U. S. Patent No. 87,157, granted to Hiram B. Everest, February 23, 1869. This patent says, in effect, that:

> Methods then in use for the preparation of the lubricants produce oils that contain tarry matters and these tarry matters render the oil so thick and sticky as to unfit it partially for use in winter and so dark as to be objected to by machinists. Further, oils of commerce as heretofore made have a disagreeable odor unless they have been subjected to the severest treatment with chemicals. Such oils contain lighter bodies that render them liable to evaporation and to corrosion. In general, oils as made for the preparation of the lubricants require to be redistilled or require severe treatment with acids and alkalies to deodorize and fit them for valuable use.

Everest suggests using steam in connection with a partial vacuum in order to overcome the present defects of decomposition. From the time of these improvements the use of steam and partial vacuum distillation with steam has been the established method of preparing the lubricants. It has been necessary, however, to acid treat, then to use alkalies, and even to filter the lubricants that were required for the most severe technical use. The draw-

[9] See "Rectification of Petroleum," by Edward Parrish, 1871, *Transactions of The Franklin Institute*, 91, p. 117.

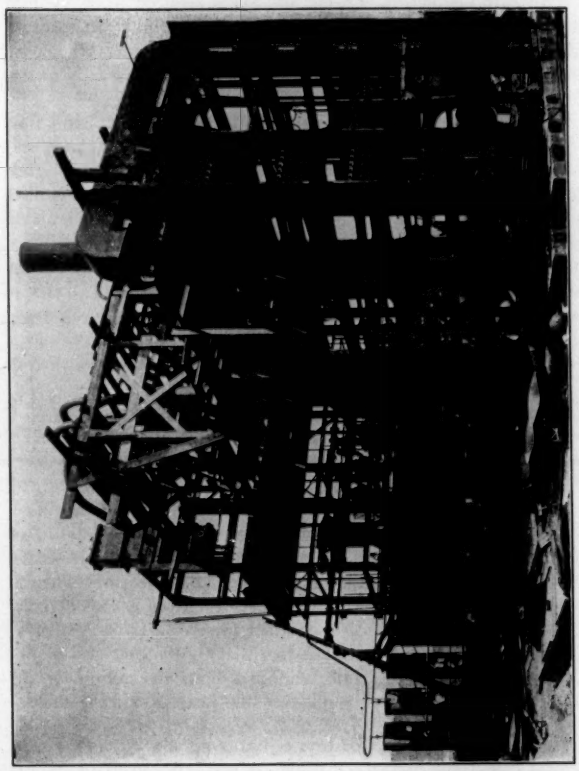


FIG. 15.

View of Z. P. R. high-vacuum still of the Zieley Processes Corporation, New York City. Still located at Bayonne, N. J., under construction.

backs of acid treatment are, of course, the increased cost, as well as the considerable losses of product. These costs and losses are the highest with fire or destructive distillation. They are reduced when steam distillation is used, and again reduced when vacuum is employed. During all of the period since Young, the form of batch-still for the production of the lubricants has remained practically the same, the goose-necks gradually giving way to the dome and to straight connections.

Oil technologists have long appreciated the fact that distillation of petroleum, carried on under the highest vacuums, with the consequent lower degree of heat, would allow the greatest production of oils with the minimum of decomposition. Oils so distilled would not require the usual corrective treatments with acid, alkali and filtration. Steinschneider [10] advocated the broad possibilities of distillation under high vacuums. His patent [11] summarizes the vacuum distillation situation to his day as follows:

> The present-day plants for distilling oils by means of a vacuum, and making large amounts of oil, do not deserve the name "Vacuum Distillation" applied to them. Properly speaking, they are only plants for distillation at a diminished pressure, and the reduction of pressure amounts to not over 250 mm., so that the vapors are really only sucked out of the still. Other defects are difficulty of maintaining the minimum pressure and allowing the fractions to issue freely; when the receiver is evacuated, the still is similarly evacuated; the still "spits" or "goes black." The above defects make redistillation necessary, or the increased use of acid to correct color.

He proposes to treat the oil in a batch-still with certain new receivers. Later, he points out [12] that there is decomposition in a batch-still, even under a high vacuum, which makes it necessary to use steam in the still. This is especially necessary when a great quantity of oil is held in a batch-still over a considerable period of time, in some cases from 18 hr.[13] to 40 hr.[14] In a batch-still the point of heat transfer is at the bottom and along the lower sides, while the full vacuum is effective only on top of the oil. The difficulty of regulating the heat over such a long

[10] See *Transactions of the International Congress of Applied Chemistry*, New York City, 1912, **25**, p. 735.

[11] See U. S. Patent No. 981,953, January 17, 1911.

[12] See *Jour. Inst. Pet. Tech.*, London, December, 1925, **11**, No. 53, p. 521.

[13] "New Vacuum Refining Process," Paul Truesdell, *Natl. Pet. News*, September 10, 1924, p. 65.

[14] Doctor Dunstan's discussion of Steinschneider's paper, "Mineral Oils," *Jour. Inst. Pet. Tech.*, **11**, No. 53, December, 1925, p. 528.

period of time is considerable. Overheating with decomposition of a considerable part of the oil is thereby caused and this must be corrected in the finished product to fit it for use.

Schulze [15] has followed Steinschneider in the use of a batch-still, with its large amount of oil undergoing distillation for many hours, and also in the general theoretical aspects of the matter. He advocates, in addition, extremely high vacuums and narrow cuts of the oils. He mentions internal bracing of the still to prevent collapsing under high vacuum, the necessity of avoiding refluxing of the condensed vapors back into the liquid in the still and the need for keeping the still tight. In his form of still the vacuum effect is several feet away from the point of heat transfer.

Doctor Brooks [16] discusses the batch-stills which are charged with very heavy crudes which should be topped carefully so as not to crack the oil. The gas oil is removed under a moderate vacuum. The vacuum is then increased to operating pressures. The lubricating oil distillate is then emulsified with sufficient concentrated caustic soda to combine with the naphthenic acids, and without separating, the mixture is then re-distilled. The oil is then heated and blown until bright. If the charging stock has not been damaged by cracking in the topping operation, and if the distillation has been properly carried out, then substantially odorless oils are produced, without any other treatment.

In both the Steinschneider and the Schulze stills which, as already pointed out, are of the batch type, I understand that it has been necessary to re-distill, acid treat and/or filter the oils for the technical market. If this is true of their commercial stills, the very object of high-vacuum distillation, which is to prevent decomposition of the oil and to avoid the necessity of acid treating and/or filtration of the distillates, is, of course, not completely realized. In short, so far as the available record shows, it is impossible to produce commercially, in *batch-stills*, even with the use of steam and the highest vacuums that can be employed, distillates which do not have to be re-distilled, acid treated and/or filtered to secure stability of color or to produce other technical advantages.

[15] See U. S. Patent No. 1,448,709, March 13, 1923.

[16] See "The Distillation of Lubricating Oils under High Vacuum," Benjamin T. Brooks, *Ind. Eng. Chem.*, **18**, No. 5, August, 1926, p. 790.

A NEW DISTILLATION UNIT.

I now have the honor of calling to your attention a different type of high-vacuum still.

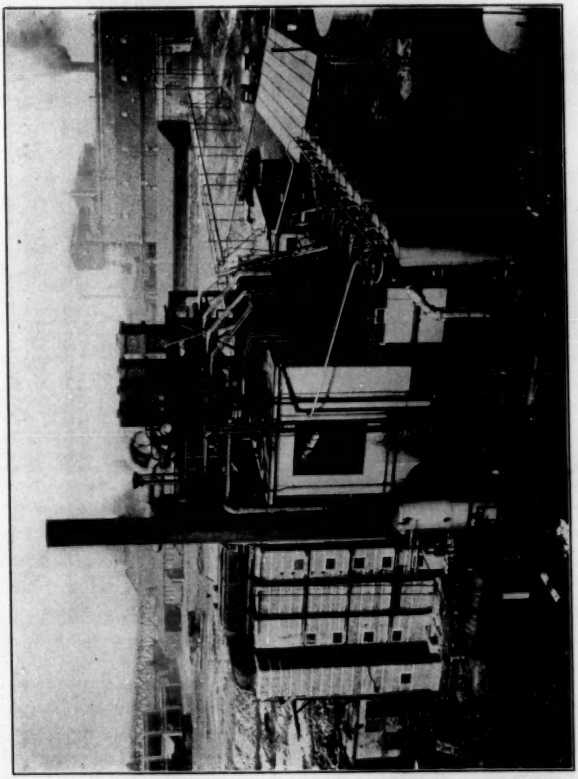
In order to overcome the imperfection of all systems attempting to distill petroleum oils under atmospheric pressure or any degree of vacuum, with or without steam, the operation, so far as possible, should be carried on under the following basic conditions:

(1) Continuous distillation.
(2) The highest vacuum, with the consequent lowest temperatures, for the removal of the fractions.
(3) Exposing a thin stream of oil to both the vacuum and the heat.
(4) Heat transfer to take place in the shortest possible time.
(5) Producing turbulence of the oil as it passes through the heat-transfer chambers.
(6) Removing all vapors as quickly as formed, keeping them separate and draining back any entrained matter.
(7) The utmost flexibility of the entire unit so that any kind of crude can be treated, and any combination of lubricants can be made, within the limit of the crude.
(8) Utmost utilization of the heat in all waste gases.
(9) Simplicity and accessibility of all parts.
(10) Low initial and operating costs.
(11) Safety in operation.

The Z. P. R. vacuum still of the Zieley Processes Corporation in my opinion substantially realizes for the first time all these ideal conditions. In the Zieley unit, the charging stock is transferred to the vacuum unit at a temperature of about 140° F. It passes through the condensers and acts as a cooling medium, picking up the latent heat from the fractions that have just left the main body of the oil. When the crude leaves the condensers it has already reached a temperature of about 360° F. It now passes to the economizer, situated in the main gas-passage to the stack. Here it picks up additional heat, its temperature being about 475° F. when it leaves the economizer.

It is discharged from the economizer into a specially designed separator, which is carried under a high vacuum. At that point

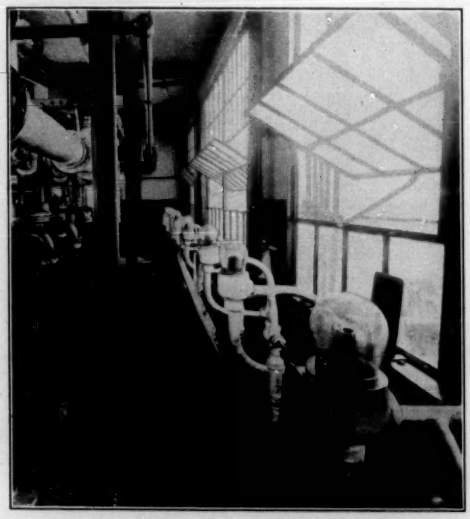
FIG. 16.



View of Z. P. R. still of the Zieley Processes Corporation, New York City. The still has a capacity of 1000 bbl. per day.

about 25 per cent. of it flashes into vapor, this vapor passing to the No. 1 condenser. The balance of the charge is then pumped to the upper tier of the *A* bank of tubes. Each bank is composed of ten stacks of 4-in. tubes, each 20 ft. long, placed at a slight angle from the horizontal. The tubes enter the headers at this angle and zigzag back and forth so that the bank takes a flattened

FIG. 17.



Look boxes and vacuum pump room. Z. P. R. high-vacuum still of the Zieley Processes Corporation, New York City.

Z shape. There are six tubes side-by-side forming each of the top five stacks of bank *A* and four tubes for the lower five stacks. In the *B* bank there are three tubes for each of the five top stacks, the bottom half being made of two tubes each. The reduction in the number of tubes is due to the decreased amount of liquid flowing through the still as the distillation proceeds. The oil flows through these ten banks by gravity, the stream being about ¼ in. thick and the speed averaging, as estimated, 70 ft. per min., completing the entire operation in about 15 min. The cascading

of the oil from the ends of the tubes into the headers, in my judgment, is effective in bringing about the desired turbulence to assist in the rapid release of the vapors.

The vapors are taken off instantly, as produced, at the forward five headers and are conducted to condensers Nos. 2, 3, and 4. The charge is then pumped from the bottom of the *A* bank to the top of the second or *B* bank and flows by gravity through these tubes, five more vapor cuts being taken off at the turbulence-producing headers and combined in condensers Nos. 5 and 6. The residue is then pumped from the bottom of *B* bank to storage. The entire tube-still and the condensers are carried under high vacuum.

CONDENSERS.

The first four condensers are Leach fractionating condensers. The last two are of special design, also fractionating. Twenty-six separate streams are taken from the condensers, which are located well up in the air. The bleeders from the condensers are connected with blending lines and the blends of the distillates pass through cooling coils by gravity to "look" boxes of special form and then to the run-down tanks. A barometric leg is maintained between the condensers on the roof and the run-down tanks. This makes it possible to keep the run-down tanks under a lower vacuum, corresponding to about 25 in. Hg. This allows the use of small vacuum pumps on the run-down system and greatly simplifies the problem of pumping the distillates out of the run-down tanks.

THE ECONOMIZER.

The flue gases, after leaving the tube-still, contain too much heat to allow it to be lost up the stack; hence, the economizer, which is of conventional design, is utilized. The separator used with it is of original design, based upon considerable laboratory study. This separator is jacketed by the warm flue gases after they leave the economizer and these same gases also pass through tubes running lengthwise through the inner compartment of the separator. These special features, combined with the fact that no head of liquid is allowed to build up in this separator, make it possible to take off a remarkably clean cut from the oil that is passing through the economizer.

QUALITY OF PRODUCT.

The high quality of the products distilled in the Zieley unit is, in my opinion, due to the following features:

(1) The high vacuum, with the consequent low temperature in the tubes of the still.

(2) The thinness and the speed of the stream while being subjected to the vacuum and to the heat exchange.

(3) The great rapidity of vaporization and the instant removal of the vapors.

(4) Low cold test, in oils containing paraffin, due to the short time of exposure to heat.

All the foregoing features result in clean lubricating distillates that have no cracked or decomposed particles. As a consequence, the lubricating distillates from all crudes are bright and clear and need no further treatment to prepare them for sale. The subsequent preparation of these distillates for medicinal or other highly technical uses is carried on much more easily and at less cost, and with but a fraction of the former loss of product.

ECONOMY.

The total fuel consumption of the unit is very low, being only about 2.5 per cent. of the total charge when distilling off 60 per cent. of the charge, and this fuel consumption approximates the theoretical limit very closely.

SUMMARY.

The art of securing various products from petroleum is very old. The distillation of petroleum has, however, been carried on under conditions where considerable losses have always occurred through

(1) Destructive distillation;

(2) Distillation with steam;

(3) Distillation under partial vacuum with steam;

(4) Distillation under high vacuum in batch-stills with or without steam.

Under all of the above forms of apparatus the distillates have required previous or subsequent treatment for corrective purposes which has entailed a varying loss of time, of money and of product.

The newest engineering development is the Z. P. R. high-vacuum still of the Zieley Processes Corporation, which corrects

the adverse conditions under which petroleum has been distilled, advancing the art to a high state of development. This results in the production of the maximum yield of lubricant of superior qualities at the minimum cost for fuel. There is but a slight additional cost for treatment, with practically no loss of product, when the oils are intended for the highest technical use.

A. ANALYSIS OF ASPHALT AND SAND.[17]

Sample A is asphalt, sand and small pieces of bone and wood taken out of the skull of a mastodon, the complete skeleton having been recovered from the Rancho-la-Brea deposits near Los Angeles, Calif. About five pounds of this material was secured. As received it was in lumps ranging in size from that of an egg down to a bean. Small particles of bone adhered to some of the lumps and a few chips of wood were impregnated with the oil. The material had a rather stale oily odor, somewhat reminiscent of used oil containing a small trace of lard, probably due to the naphthene ends. This was designated Sample A.

Sample B is a heavy oil recently removed from the same pool and is intended to represent present-day asphaltum from the same source.

The following analyses were made by the Research Laboratories of the Zieley Processes Corporation, with the exception of the Penetration Tests and the Sand Tests, which were made in the Research Laboratories of The Texas Company, New York:

	Sample A from Skull.	Sample B from Pool.
Soluble in CS_2	16.62%	67%
Sand	82.11%	33%*
Screen test above sand.		
200 mesh passes	Trace	7.8%
100 mesh passes	44.0%	14.8%
80 mesh passes	7.0%	7.0%
60 mesh passes	12.4%	12.7%
50 mesh passes	11.2%	14.8%
40 mesh passes	10.2%	14.8%
30 mesh passes	5.0%	8.4%
20 mesh passes	4.6%	7.8%
10 mesh passes	3.2%	4.9%
¼″ mesh passes	2.4%	7.0%
	100.0%	100.0%
Asphalt soluble in petroleum.		
Ether gravity 85.2 A.P.I.	55.24%	79.7%
Carbones	3.66%	1.45%
Volatile at 325° F.	16.9%	16.9%

* The 33 per cent. insoluble in CS_2 on Sample B consisted of sand, wood and insects.

[17] From a paper by Dr. Chester A. Reeds in the *American Museum Novitates*, 1927.

	Sample A from Skull.	Sample B from Pool.
Sp. gr.	1.051	1.08
Appearance	Black	Black
Lustre	Good	Good
Consistency	Soft	Semi-liquid
Homogeneous	Yes	Yes
Penetration test.		
At 32° F., 200 grs. 60 sec.	16	146
At 77° F., 100 grs. 5 sec.	32	220
At 115° F., 50 grs. 5 sec.	35	Soft
Asphaltum after losing volatile matter at 325° F.		
Appearance	Black	Black
Lustre	High	High
Sp. gr.	1.075	1.09
Streak on porcelain	Black	Black
Consistency	Hard	Hard
Raw material separated from bones and wood.		
Soluble in petroleum ether	9.18%	53.1%
Extracted material (by petroleum ether).		
Appearance	Black	Black
Consistency	Semi-liquid	Semi-liquid
Separated pieces.		
Wood and pieces like bone	8.56%	
Wood washed with CCl_4	7.57%	
Ash of one-piece bone	22.8%	
Bones on heating and burning do not produce odor of burning horn.		
Ash †	1.38%	
Color of ash	Reddish-brown	
Bones contain carbonates		
Asphaltum extracted from bones	10.15%	
Sand washed with CS_2.		
Matter soluble in cold or hot toluol	None	
CO carbon, possibly some organic matter.	4.02%	
Much CO_2 but no quantitative determination was made.		

† The ash is mineral matter previously combined with organic matter.

B. BITUMEN.[18]

Bitumen is called asphalton by the Greeks, probably from Lake Asphaltites in Judæa, which is now called the Dead Sea, where Sodom and Gomorrah formerly were. For that Lake gives forth that sticky asphalton, adapted for human use; otherwise the Lake is perfectly barren. Bitumen is also found in

[18] From "The Origin, Variety and Nature of Metals, Minerals, Precious Stones, Etc.," by Christophorus Encelius (Christoph Entzelt), 1551, Frankfort. Translated from the original Latin by Prof. Harry M. Hubbell, Yale University, New Haven, Conn., 1926.

Assyria and Chaldæa in such quantities that it is used as cement in building walls. Semiramis is said to have used it in constructing the walls of Babylon. It is said, moreover, that bitumen is produced in Babylon because of the frequency of thunderbolts there. Bitumen is nothing but very sticky slime, extracted from water, resembling pitch, as it were earthy pitch. That is why Dioscorides in the first book mentions bitumen after pitch; and enumerates the various kinds called, from their place of origin, Phoenician, Babylonian, Zacynthian and Sicilian. He also tells us that it is good when it is dark red or has a reddish bloom; contrariwise bad and defective when it is black. As to consistency, there are two kinds of bitumen; sticky and hard, found in the earth, and liquid in water and springs, floating according to Curtius. This they used as oil, improperly calling it Sicilian Oil. Pliny in one place asserts that bitumen is slime, in another place earth. The slime, doubtless, is that which comes from the Lake in Judæa. He tells us that in Babylonia it occurs in the form of a white liquid, which is pissasphalton; and it is more liquid, and more closely resembles the nature of pitch. Bitumen from the earth is beautifully described by Ovid in the Metamorphoses.

"Or as the sticky bitumen oozes from the heavy earth. However, the kind from Judæa is the best."

(Bitumen) is undoubtedly a species of naphtha, but not naphtha itself, as some claim. See Serapion under the heading Brafalendum. For naphtha is petroleum and liquid oil. But bitumen or asphalt is a hard unyielding substance, which can sometimes be pulverized but cannot be resolved into elements; it has the odor of naphtha. I am surprised, however, that it is found in water, an element so hostile to fire; for it is such an inflammable material that when water is poured on it when burning it blazes more fiercely.

Nicander, in his treatise on antidotes to poisons, says that bitumen is efficient in driving away poisonous serpents. Bitumen certainly has a beneficial effect on epileptics when taken in wine; it drives out the quartan ague by its force and the pungency of its odor. It is not surprising then that it drives away reptiles. It was also used formerly for coloring statues and hardening iron. Consult the Arabians, also Dioscorides, Pliny, Solinus, Strabo and others.

We will also add a few remarks about pissasphalton. This is more liquid than bitumen, and gets its name from pitch and bitumen, perhaps because it smells like pitch mixed with bitumen. There are two kinds of pissasphalton: the natural product and the artificial manufactured from pitch or pine and bitumen. Dioscorides describes the natural in the eighty-third chapter of the first book. Pliny describes the artificial in the seventh chapter of the twenty-fourth book. "Wann man bitumen und bech zusamen schemltzet."[19] This is a remedy for scab in sheep according to the passage in the Georgics.

"Pitch from Ida and black bitumen, etc.," unless you understand by "black bitumen" the dirty kind, or the Sicilian liquid variety. The natural pissasphalton is found in the territory of the Apollonitæ in Epidaurus. But more about this later.

[19] Apparently Encelius got his Pliny in a German translation: "When tree pitch and bitumen are melted together."—TRANSLATOR.

NAPHTHA.

We have said that bitumen from Judæa is *a species of naphtha and not naphtha* itself since naphtha is nothing else but petroleum, that liquid oil which travelers[20] bring to us in a corrupt state. Dioscorides in Book 1, chapter 84, says that the Babylonians call naphtha distillate from bitumen, and it exists or is found both white and black.

White naphtha is our petroleum. The black kind, which is perhaps the pitchy and sticky kind of Amianus, closely resembles bitumen, and when burning can only be extinguished by smothering it with sand. Similarly that slime described by Pliny, derived from the Lake in Comagene, is extinguished with dirt. This black naphtha was regarded among the ancients as devils' ordure. Now we regard assafœtida as devils' ordure. But I would not dogmatize on this subject. Many objects with an offensive odor were highly valued by the ancients. But naphtha is very inflammable as Dioscorides says (in the passage quoted) and Pliny in Book 2, chapter 108. There is nothing which kindles quicker and keeps a fire going more fiercely than naphtha. Pliny tells the story about a concubine burned to death by Medea. The woman was approaching an altar to make sacrifice, wearing a crown of naphtha, when the fire ignited the crown and consumed her. Naphtha, according to Pliny, is a substance which flows forth in and about Babylonia and among the Austageni in Porthia, like liquid bitumen. There are two kinds of naphtha, the natural described by Pliny, which is properly petroleum, the second artificial, which is the refined bitumen according to Dioscorides. And one species of this, the white, may be a species of petroleum, but not as good as the natural. But the other species, the black, may be devils' ordure, according to the ancient belief. It is from *this*, I mean from the finer bitumen, *i.e.*, naphtha which is the genuine petroleum, when hardened by the influence of the sun, as Ovid says about amber, that lignite is produced in the sea, and not from that artificial white naphtha.

Failure to observe this led Serapion astray and so there are two kinds of bitumen occurring in water and in earth; liquid hard and viscous. There are two kinds of pissasphalton, natural and artificial; two kinds of naphtha, natural and artificial, which is a refined bitumen, white or black. So bitumen, pissasphalton and naphtha are different varieties of the same substance. So with the mineral lignite when it is made of natural naphtha, *i.e.*, of real petroleum, as its odor easily proves. The mineral called Thracias, another species of lignite, is possibly made of black bitumen or black naphtha, for this, too, burns in water and is extinguished by oil.

On the other hand, amber is the resin of trees. It has the power of attracting threads and straws. Amber does not burn in water on account of the weakness of resin, but lignite burns more fiercely in water on account of the force of the bitumen or naphtha of which it is composed. In the same way those hard stony coals, "die Steinkole," which are mined in our country, are a variety of lignite, both the light and heavy kinds. These are nothing but bitumen hardened or baked under the earth. This kind of stone is extinguished

[20] The word I have translated by "travelers" is "agyrtæ," a borrowing from the Greek. It means originally a wandering priest or fakir, and then merely wanderer or tramp. Just what Encelius means I do not know. Perhaps "gypsies" or "mendicant friars" or "palmers."—TRANSLATOR.

by oil, and when sprinkled with water burns more fiercely, which is the nature of bitumen. And these coals of bitumen are the reason (according to Pliny) why mountains like Aetna and Vesuvius are on fire. The same phenomenon we see in many places in Germany and they burn brighter by night than by day, because the heat of the sun puts out that fire or deadens it, in the night which is damp and cold the fires are kindled again by the moisture.

Also that variety of pyrites, that fissile stone of Islebial "der schyster" seems to consist of bitumen; partly because it burns easily and gives off an odor something like bitumen, partly because this mineral is most suitable for receiving impressions as we have said before. For, as the chemists say, the soul easily and quickly enters its own proper body: So under the force of ever active Nature, in that bituminous stone under the earth impressions are easily made, as in a material which readily responds to force. But enough of this.

Petroleum, *i.e.*, naphtha, which the travelers bring to us, does not flow from the Tomb of some saint, as they falsely say. That is a fairy story. There is another artificial naphtha, quite a different thing, an artificial poison described by Nicander whom you may consult in his "Alexipharmaca." We have mentioned above the variety of bitumen found in Saxony, called "thorff."

Quality of Water and Industrial Development.—W. D. COLLINS (U. S. Geological Survey, *Water Supply Paper 559*, 1–43, 1926) has studied the relations between the quality of the water supply and industrial development in the United States. The following industries are dependent on the quality of the water; industries in this group have grown during the last fifty years almost entirely in states with soft or only slightly hard waters, and have contributed comparatively little to industrial development in regions with hard waters: Chemicals, cotton manufactures, druggists' preparations (including patent medicines and compounds, perfumery, and cosmetics), dyeing and finishing of textiles, knit goods, leather (tanned, curried, and finished), distilled liquors, paper and wood pulp, silk manufactures, and wool manufactures.

The following industries are not dependent on the quality of the water. They have contributed largely to the industrial development of regions with hard water: Agricultural implements, automobiles, boots and shoes, brass, bronze, and copper products, canning and preserving, cars and steam-railroad shops, clothing for men and for women, electric machinery (including apparatus and supplies), engines (gas, steam, and water), fertilizers, foundry and machine-shop products, furniture, glass, iron and steel, jewelry, lumber and timber products, petroleum refining, and the rubber industry.

A third group of industries has been located with reference to population regardless of the quality of the water supply, and has contributed uniformly to industrial development in regions which have waters of all degrees of hardness: Automobile repairing, bread and other bakery products, confectionery and ice cream, products of flour mills and grist mills, gas for illumination and heating, malt liquors, printing and publishing, slaughter houses and meat packing, power laundries, and tobacco. J. S. H.

Changes Produced in Milk by Freezing.—WILLIAM H. E. REID (*Proc. Ann. Conf. Am. Asso. Med. Milk Commissions and the Certified Milk Producers' Asso. Am.*, 1926, **20**, 328–337) has studied the changes which occur in the flavor and the cream line of milk on freezing. The temperatures used were 0, 6, 10, 15, 20, 25 and 30° F. The period of holding in the frozen condition was either three or five hours. The cream column of the milk was diminished, and the decrease in its height became greater, the lower the temperature of freezing and the longer the period of holding in the frozen condition. The fat globules, which are normally isolated and of uniform size and shape, become distorted, of irregular size and shape, and aggregated into clumps. These changes are attributed to a destruction of the emulsion of the butter fat by the freezing. For several hours after thawing, the cream column appeared granular and porous. When milk was kept frozen for three hours at a temperature of 10° F., then thawed, any objectionable odor was intensified, and even rendered offensive. J. S. H.

STATISTICAL MECHANICS AND ITS APPLICATION TO PHYSICAL-CHEMICAL PROBLEMS.

BY

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LECTURE III.—SOME APPLICATIONS OF STATISTICAL MECHANICS TO SYSTEMS THAT ARE CHANGING TOWARDS THE CONDITION OF EQUILIBRIUM.*

BARTOL RESEARCH FOUNDATION

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(1) *Introduction.*—In the last lecture we considered some of the many applications of statistical mechanics to systems of molecules that are in a condition of equilibrium. In our introductory discussion of statistical mechanics, however, we called special attention to the fact that this science is superior to thermodynamics in leading to theoretical predictions as to the rates at which gross physical-chemical changes will take place in systems which have not come to a state of equilibrium. This is to be the subject of our considerations to-day.

The most general prediction furnished by statistical mechanics as to the nature of the physical-chemical changes which will take place in a system which has not already come to equilibrium, is that the direction of the change will be towards a more probable distribution of the molecules. Thus, for example, in the case of a gas in which the molecules do not have the positions, velocities, and internal conditions corresponding to the Maxwell-Boltzmann distribution law, we may expect in general a readjustment of the configuration in such a way as to conform to the Maxwell-Boltzmann distribution.

The justification for this prediction may be seen by considering the motion of the representative point for the gas in the generalized phase space (γ-space) which may be used for plotting the values of the coördinates and momenta which determine the state of the gas. Nearly the whole of the volume of this phase space corresponds to configurations in which the molecules have approximately the most probable configuration, and a very rapidly decreasing fraction of the space to the configurations that differ increasingly from this most probable Maxwell-Boltzmann con-

* Delivered in the lecture hall of the Institute, Monday afternoon, November 22, 1926.

dition. Furthermore, in accordance with Liouville's theorem the representative point has no tendency to linger in any particular region of the phase space, and in accordance with the ergodic hypothesis may be regarded as travelling on a continuous path which visits substantially all regions of the phase space in succession before returning to its starting-point. Hence it is evident that when the representative point spontaneously leaves the regions of the phase space which correspond to the Maxwell-Boltzmann configuration, it will remain outside only for a time which is short compared with that in which the Maxwell-Boltzmann law is obeyed; and furthermore that a system arbitrarily started in a state, where it is not in equilibrium, when left to itself, will in general move in the direction of configurations in which the Maxwell-Boltzmann distribution prevails.

The above conclusion is analogous to the thermodynamic conclusion that systems tend to readjust themselves in the direction of increasing entropy, and it is apparent that the statistical mechanical state of maximum probability corresponds to the thermodynamic state of maximum entropy. It should be noted, however, that the statistical mechanical state of maximum probability specifies the values of *microscopic* variables belonging to the individual molecules of the system, while the state of maximum entropy merely specifies the values of *macroscopic* variables belonging to the system as a whole, so that even on the basis of these partial considerations we obtain from statistical mechanics a more complete account of the result of a physical-chemical change than we do from thermodynamics.

Nevertheless, neither the thermodynamic conclusion that systems tend to change in the direction of increasing entropy, nor the statistical mechanical conclusion that they move in the direction of the Maxwell-Boltzmann configuration, provide information as to the velocity or real nature of the process by which physical-chemical changes take place, and we must now proceed to our main business of studying the actual rate and internal mechanism by which systems do approach the statistical mechanical state of maximum probability. I may say in advance that we must not expect to achieve specific results in this field too easily. The rates at which gross physical-chemical changes take place must on analysis be dependent on the rates at which specific atomic or molecular changes can take place; and hence a detailed knowledge

of atomic mechanics would be necessary before we could make absolutely *a priori* predictions as to the rates of physical-chemical processes.

(2) *Boltzmann's H-theorem.*—I feel that the most fundamental contribution to the problem of rates of physical-chemical change is furnished by Boltzmann's justly famous H-theorem, which furnishes us with an expression for the rate at which a gas disturbed from equilibrium will approach the Maxwell-Boltzmann distribution owing to the result of the collisions between its molecules.

Boltzmann considers a system containing a large number of molecules of each of the kinds present, uniformly distributed throughout the space available, but with a distribution of velocities and internal conditions which deviates from the final Maxwell-Boltzmann distribution.

Taking N_i as the number of molecules in any particular state i, Boltzmann defines the quantity H by the equation

$$H = N_1 \log N_1 + N_2 \log N_2 + N_3 \log N_3 + \cdots = \sum_i N_i \log N_i \qquad (1)$$

where the summation is taken over all the different states of the different kinds of molecules. This is the quantity which Boltzmann is going to take as a measure of the deviation of the system from equilibrium conditions. When a collision occurs, the value of H will in general be changed, since the distribution of molecules in the different states i will be changed. By arranging the different possible kinds of encounter in what may be called cycles of corresponding collisions, Boltzmann finds it possible to obtain an expression for the *probable* rate at which H will be changing with the time, and to show that this probable rate must always have a negative or zero value. Hence H is a quantity which tends to decrease with the time to a minimum value and then to remain constant. Furthermore, as you have already suspected, when H reaches its final minimum value, the distribution of molecules in the different states is that required by the Maxwell-Boltzmann distribution law.

The primary value of this theorem is to show that the Maxwell-Boltzmann distribution is not only the most probable condition for the molecules of a gas, which was already known, but in addition that there is an actual tendency for the molecules

to approach this distribution. This tendency is shown by the equation which Boltzmann obtains for the probable value of $\frac{dH}{dt}$. It must be remarked, however, that although Boltzmann's analysis shows that $\frac{dH}{dt}$ can only be negative or zero, the expression contains coefficients whose absolute values are not known, although conceivably capable of empirical determination. Hence Boltzmann's expression for $\frac{dH}{dt}$ does not yet tell us how rapidly the state of equilibrium is actually approached. This is an example of the difficulty, already mentioned, of obtaining any completely *a priori* prediction of actual rates.

(3) *Extensions of Boltzmann's H-theorem.*—It is also to be noted that Boltzmann's H-theorem considers only the effect of *collisions* in bringing about a condition of equilibrium. Other processes, however, may be involved or be necessary in the process.

Thus Boltzmann assumes for convenience a uniform distribution of the different kinds of molecules in their different states. Hence the total process of attaining equilibrium will have to involve diffusion as well as collision. This, however, is of course adequately cared for.

In addition to changes in molecular state by collisions, we also have, however, the possibility of changes in state by the absorption and emission of radiation, a matter which physicists now understand perhaps imperfectly but nevertheless much better than in Boltzmann's time. To take care of this, I have recently found it possible to set up a somewhat more generalized expression for H, including radiation as well as matter.

The expression for H, in question, has the form

$$H = \sum_i N_i \log N_i + \sum_{ij} n_{ij} \log n_{ij} - \sum_{ij} (n_{ij} + m_{ij}) \log (n_{ij} + m_{ij}). \quad (2)$$

The first term in this expression is exactly the same as in Boltzmann's expression, N being the number of molecules in any state i. The quantity n_{ij} occurring in the other two terms is the number of quanta of radiation present which can affect a molecular transition from state i to state j, and m_{ij} is the number of modes of electromagnetic vibration in the container which have this frequency.

It is possible to show that this generalized H also tends to

decrease with the time to a minimum value. And when the minimum value of H is reached, not only do we have the Maxwell-Boltzmann distribution for the molecules, but we also have the Planck distribution for the radiation. I think that the procedure adopted may seem a little artificial, especially in connection with the introduction of the number of modes of vibration m_{ij} which is sort of dragged in from classical theory. Nevertheless, it is interesting to obtain so simply a combined deduction of both the two distribution laws for matter and radiation.

(4) *Critique of the H-theorem.*—Before proceeding we must call attention to the important fact that the expression given by Boltzmann for the change of H with the time is only an expression for the *probable* rate of change. This arises from the circumstances that the expressions, which he uses for the number of collisions of different kinds that take place per second, are merely expressions for the probable number of collisions. Hence when H is appreciably displaced from its minimum value, there is a great probability that it will decrease but not a certainty. Similarly when H has reached its minimum equilibrium value, the result of collisions may sometimes lead to a temporary increase in its value.

The above consideration is of great importance in removing misconceptions as to the behavior of molecular systems. In accordance with the ergodic hypothesis the representative point for a system of molecules will in the course of time wander into all regions of the phase space (γ-space) permitted by the energy content of the system, the predominant duration of the system in states according with the Maxwell-Boltzmann distribution law being assured merely by the relatively great fraction of the total phase space which corresponds to such a distribution. To account for the occasional intervals when the system does forsake the Maxwell-Boltzmann distribution, we must evidently permit the occurrence of corresponding occasional increases in the value of H above its minimum. We now see, however, that this is permissible, since the expression we have obtained for the decrease of H with time is merely an expression for the *probable* rate of decrease, and does not rule out occasional increases.

A difficulty sometimes arises in understanding the compatibility of the occasional increases permitted to H with the great probability that H when displaced from its minimum value will

decrease. Thus, for example, if H_0 is the minimum value and H_1, H_2, and H_3 appreciably higher values, and we permit an occasional increase in H, say from H_1 up through H_2 to H_3 and its later return back through H_2 to H_1, it may at first sight be difficult to see why the tendency of the system to pass from H_1 to H_2 on the upward course is not just as great as to pass from H_2 to H_1 on the downward. The clarification of this difficulty is particularly due to P. and T. Ehrenfest,[1] who have pointed out that we must regard the change of H with the time as a step-like process of such a nature that the attainment of any value, appreciably different from H_0, such as H_2, is far more often followed immediately by return to a lower value than by passage on upward to a higher state. Thus the change

$$\begin{array}{ccc} & H_2 & \\ H_1 & & H_1 \end{array}$$

will occur far more frequently than

$$\begin{array}{ccc} & H_3 & \\ H_2 & & \\ H_1 & & \end{array} \quad \text{or} \quad \begin{array}{ccc} & H_3 & \\ & H_2 & \\ & & H_1 \end{array} \quad \text{or} \quad \begin{array}{ccc} & H_2 & H_2 \\ H_1 & & \end{array}$$

Hence in the great majority of cases, when the value of H_2 is attained, it forms a sharp peak of the trajectory and is immediately followed by return to a lower value. Hence taking any given system with the value H_2, there will be a great probability that H will at once move in the direction of a lower value.

These considerations also eliminate the difficulty in understanding what the behavior of a system would be if at any instant all the velocities should be reversed. If the tendency of H is to decrease in the forward motion, it has sometimes been felt that the tendency in the equally representative reverse system would be for H to increase, and the system to change into more and more improbable configurations. This misapprehension, however, is also removed by the Ehrenfestian considerations, since in the reverse motion as well as in the forward motion high values of H occur in the great majority of cases as peaks on the trajectory, so that also in the reverse motion there is a great tendency for a given system with a high value of H to move in the direction of lower values.

[1] P. and T. Ehrenfest, "Encyklopädie der mathematischen Wissenschaften IV," **32**, p. 42, Leipzig, Teubner, 1907–1914.

We cannot conclude these remarks on the H-theorem without an expression of admiration for Boltzmann's masterful achievement in discovering and deducing the theorem, even though his deserved and honored fame needs from us no words. The significance and originality of inventing a function which should measure the displacement of a system of molecules from statistical equilibrium, and the ingenuity and elegance of the proof that this function will decrease with the time alike compel attention.

The analogy between increase in the thermodynamic quantity entropy and decrease in the statistical mechanical quantity H is evident. And the attempts to relate the entropy S to the negative of H should not be overlooked. The new statistical mechanical quantity, however, certainly gives the greater insight into the inner mechanism of physical-chemical changes.

The cosmological implications of his theorem were also appreciated by Boltzmann. In whatever part of the whole universe or instant in time we may find ourselves, there is an enormous probability that the value of H will be decreasing with the time, unless it has already reached its minimum value, and we shall label forward in time that direction in which H decreases and energy is dissipated, and perhaps look longingly backward to the good old days when there was a greater store of undissipated energy. But in the course of time enormous, however, compared with that which we label eons, the value of H may again increase and prepare for a new cycle of significant events.

(5) *Transport Problems.*—Having discussed with the help of Boltzmann's H-theorem the general nature of the approach of a molecular system towards equilibrium, we must now turn our attention to the more specific consideration of the rates at which various processes are actually found to occur.

There is one large and familiar class of processes whose rates have long been studied by statistical mechanical or, if you prefer, by kinetic theory methods, namely, the rates of transport by gases of momentum, energy, and matter. The usual method of handling these problems is to calculate the mean free path of molecules or distance that they travel on the average between collisions, by making use of Maxwell's law for the distribution of their velocities. If, then, we have a gas which is disturbed from a steady state, we can calculate how fast this disturbance will be trans-

mitted past any boundary in this gas by determining the average distance travelled since their last collision by the molecules that cross the boundary, and assuming that at their last collision they acquired on the average the amount of the disturbance characteristic of the location of that last collision. We thus obtain treatments of viscosity, thermal conductivity, and diffusion which in their broad outlines are undoubtedly correct.

I wish to warn you here, however, against an interesting difficulty which, though appreciated by Maxwell and Boltzmann, is often forgotten. In the case of a gas which is transporting momentum, energy, or matter, the system is obviously not in equilibrium, since if it were, evidently no such transport would be taking place. Hence a calculation based on the assumption of the Maxwell distribution, which holds only at equilibrium, contains a logical inaccuracy at its very foundation, and special investigations must be made to determine how seriously the results are thereby affected. In some cases it is found that the assumption of the Maxwell distribution quite definitely affects the results, and this accounts at times for the lack of exact agreement between the numerical coefficients found by experiment and those predicted by the elementary theory.

The elaborate investigations of Jeans[2] on the persistence of velocity in collisions were made with a view to overcoming this difficulty. I must also call your attention to the beautiful, but mathematically extremely complicated, work of Chapman,[3] who treats the problem of viscosity by determining the actual non-Maxwellian distribution of velocities that may be expected to hold in a gas that is transporting momentum. He has thus been able to obtain an almost exact agreement between the values of molecular diameters calculated from viscosity measurements and from van der Waal's b, a very satisfying achievement.

In the case of gases at extremely low pressures, where the mean free path becomes large compared with the dimensions of the apparatus, the treatments of viscosity, thermal conductivity and diffusion become very simple, as shown by the long series of theoretical and experimental investigations made by Knudsen in Copenhagen, and many of you are doubtless familiar with the applications of this work in connection with high-vacuum tech-

[2] JEANS, "Dynamical Theory of Gases."

[3] CHAPMAN, *Phil. Trans. Roy. Soc.*, **216**, 279 (1916).

nique. Here too, however, you must be on your guard lest the assumption of Maxwellian distribution should unduly falsify your predictions.[4]

(6) *The Rate of Chemical Reaction.*—In the time remaining you must allow me to make some remarks about another rate problem which is very much in my thoughts, namely, the rate of chemical reaction.

The rate at which chemical reactions proceed is one of profound interest both for theory and practice. With the help of thermodynamics it is now possible in large measure for chemists to predict in advance just which chemical reactions can take place, namely, those accompanied by an increase in entropy, and to calculate how far they will go before equilibrium is attained. The laws controlling the specific rates at which these reactions proceed are, however, beyond the scope of thermodynamic reasoning, and hence the thermodynamist is not in a position to foresee what will actually happen when chemical materials are mixed together, since his knowledge of the thermodynamically possible reactions does not suffice for the prediction of the actual reactions which do occur. Indeed by a strange perversity, it often seems as if the reactions which are accompanied by the largest increases of entropy, as, for example, the combination of hydrogen and oxygen to form water, take place at the slowest rates,[5] while reactions which have almost no thermodynamic tendency to proceed, as, for example, the dissociation of nitrogen peroxide into the dioxide, take place at speeds so great that they still defy experimental measurement.

The ultimate solution for such problems of reaction velocity cannot be looked for in the field of thermodynamics which entirely

[4] See SMOLUCHOWSKI, *Ann. der Phys.*, **33**, 1559 (1910).

[5] Reactions having a large thermodynamic tendency to proceed are in general exothermic, and in some cases the slow rate of reaction may be due to the difficulty of providing an escape for the excess energy from the molecule formed. Thus the combination of monatomic hydrogen to form molecular hydrogen in its normal state

$$H + H = H_2$$

involves the emission of an enormous amount of energy, and if we assume that the non-polar character of the hydrogen molecule prevents the emission of this energy in the form of radiation, a three-body collision would be necessary for the reaction. This hypothesis is in agreement with the slow rate of recombination of monatomic hydrogen and its catalysis by solid substances which can conduct away the heat.

neglects the atomic and molecular structure of matter. The mechanism of chemical reaction seems certainly determined by the nature of the interacting atoms themselves. In the case of the individual processes which occur, the question is one of atomic and molecular mechanics, which for the overall rate of change in collections of molecules, the problem is certainly one of statistical mechanics.

(7) *The Existence of Homogeneous Non-catalyzed Gas Reactions.*—For the purposes of statistical mechanical study it is evident that we should prefer to use homogeneous, non-catalyzed gas reactions, since the processes involved will then be most easily treated by statistical mechanical methods. There has apparently been a doubt in the minds of some chemists, however, as to whether any such reactions actually exist. One school of thought has apparently felt that all gas reactions are really heterogeneous, taking place on the walls of the vessel. And the other school of thought has apparently felt that gas reactions, if they ever are homogeneous, take place through the action of some mysterious catalyst present in small amounts, even in the purest gas.

I think that both of these suspicions can now be quieted by the facts concerning a number of reactions. I shall choose, however, only a single example of homogeneous non-catalyzed reaction to talk about, namely, the decomposition of gaseous nitrogen pentoxide in accordance with the equation

$$N_2O_5 \longrightarrow \underset{\uparrow\downarrow}{N_2O_4} + \tfrac{1}{2}O_2.$$
$$2NO_2$$

The rate of this reaction was first studied by Daniels and Johnston in the Fixed Nitrogen Research Laboratory in Washington, while I was a director of that laboratory. I am extremely happy to be able to say that as far as I know I never did anything to prevent the expenditure of the people's money in the study of this absolutely useless reaction which could never by any conceivable chance be of any practical importance to anybody. And I am very proud to have thus been dimly associated with a study which has been so enormously important for the theory of chemical reactions, even though I myself made no actual contributions to Doctor Daniel's beautiful work.

At a given temperature and concentration this reaction is

always found to proceed at the same rate. This rate is independent of the walls, as shown by Daniels and Johnston by filling their bulbs with glass wool. And the rate does not appear to depend on the presence of unknown homogeneous catalysts, since pure nitrogen pentoxide can be taken in varying amounts and mixed with varying amounts of oxygen and nitrogen without effect on the specific rate of decomposition, although such procedure would certainly have varied the concentration of the unknown catalyst if one existed.

(8) *Rate of Decomposition of Nitrogen Pentoxide.*—I wish to use this decomposition of nitrogen pentoxide as the best example to illustrate the possibility of applying statistical mechanics to chemical reactions. The reaction proceeds with a first order rate in accordance with the equation

$$-\frac{dC}{dt} = kC \qquad (3)$$

where C is the instantaneous concentration of nitrogen pentoxide at the time t. At a given temperature the specific reaction rate k is found to be constant under a wide variety of conditions. It has the same value at the very start of the reaction as later on,[6] and the value is the same for pure nitrogen pentoxide as for nitrogen pentoxide mixed with 1000 times its volume of oxygen,[6] or with 76,000 times its volume of nitrogen,[7] and indeed it has nearly the same value when the pentoxide is dissolved in carbon tetrachloride or in chloroform.[8]

The first order character of the reaction over such a wide variety of conditions, combined with the evidence as to the absence of any catalytic action, make it at least almost absolutely necessary for us to believe that the rate determining mechanism of the reaction is itself unimolecular. Such an assumption would of course immediately explain equation (3), since if the process of decomposition involves only a single molecule of pentoxide, the number decomposing at any time would evidently be proportional to the number present, the specific reaction rate k being the chance per second that a molecule will decompose.

(9) *The Temperature Coefficient of the Rate of Decomposition.*—If we turn now to the effect of temperature on the

[6] See WHITE and TOLMAN, *Jour. Amer. Chem. Soc.*, **44**, 1240 (1925).
[7] See HUNT and DANIELS, *Ibid.*, **47**, 1602 (1925).
[8] See LUECK, *Ibid.*, **44**, 757 (1922).

rate of decomposition, we find, as in so many typical chemical reactions, that the specific rate k increases rapidly with the temperature. The results of the measurements made at different temperatures can be expressed by an equation of the form

$$k = 4.56 \times 10^{13} e^{-\frac{24700}{RT}} \qquad sec^{-1}$$

$$\frac{d \log k}{dT} = \frac{24700}{RT^2} \tag{4}$$

where the so-called energy of activation 24,700 is given in calories per mol.

To explain this temperature coefficient, we are naturally and almost inevitably led to some form of the Arrhenius picture, which assumes that molecules in their normal states are not reactive, but that they can only react when specially activated, the number of such activated molecules increasing rapidly with the temperature. Arrhenius was inclined to regard the activated state of a molecule as being an isomeric form of the original molecule, but nowadays we somewhat broaden the picture to include higher quantum states of the original molecule, as well as on occasion the products produced by some preliminary decomposition or other chemical reaction into which the molecule may enter.

If we assume such a picture of chemical reaction, we can easily interpret an equation of the form of (4). Let us suppose, for example, that the decomposition of nitrogen pentoxide is due to the presence of molecules in higher quantum states. If the mechanism of activation is fast enough to maintain the full Maxwell-Boltzmann quota of molecules in the higher quantum states, we can then write for the number of molecules in any activated state a, the expression

$$N_a = \frac{N p_a e^{-\frac{\epsilon_a}{kT}}}{\sum_i p_i e^{-\frac{\epsilon_i}{kT}}}, \tag{5}$$

and for the rate of decomposition

$$-\frac{dN}{dt} = \frac{N \sum_a k_a p_a e^{-\frac{\epsilon_a}{kT}}}{\sum_i p_i e^{-\frac{\epsilon_i}{kT}}} \tag{6}$$

where k_a is the spontaneous chance of decomposition per second of a nitrogen pentoxide molecule in the particular activated state a, and the summation is to be taken over all activated states that contribute appreciably to the rate of decomposition. If we knew the values of k_a and ε_a for all the different activated states, this expression would of course permit an immediate prediction of the rate at any temperature. In the absence of such knowledge, however, we can nevertheless use this equation to obtain a conclusion as to the temperature coefficient of reaction rate. The quantity

$$\left(\sum_a k_a p_a e^{-\frac{\varepsilon_a}{kT}}\right) \Big/ \left(\sum_i p_i e^{-\frac{\varepsilon_i}{kT}}\right)$$

occurring in equation (6) is evidently the chance per second that a molecule will decompose, and hence a theoretical expression for the specific reaction rate k. If we differentiate this with respect to the temperature, we easily obtain

$$\frac{d \log k}{dT} = \frac{1}{k} \frac{\sum_a k_a p_a e^{-\frac{\varepsilon_a}{kT}} \frac{\varepsilon_a}{kT^2}}{\sum_i p_i e^{-\frac{\varepsilon_i}{kT}}} - \frac{\sum_i p_i e^{-\frac{\varepsilon_i}{kT}} \frac{\varepsilon_i}{kT^2}}{\sum_i p_i e^{-\frac{\varepsilon_i}{kT}}}. \qquad (7)$$

The first term of this expression, however, evidently gives the average energy of the activated molecules that actually react and the second term is the average energy of all the molecules, so that the equation may be rewritten in the form

$$\frac{d \log k}{dT} = \frac{\bar{\bar{\varepsilon}}_a - \bar{\varepsilon}_i}{kT^2} = \frac{\bar{\bar{E}}_a - \bar{E}_i}{RT^2} \qquad (8)$$

where the double line indicates the average energy for the molecules that actually react and the single line the average energy for all the molecules. This quantity $\bar{\bar{\varepsilon}}_a - \bar{\varepsilon}_i$ per molecule or $\bar{\bar{E}}_a - \bar{E}_i$ per mol is evidently on the average the energy that has to be supplied to the molecules that react and may be called the *energy of activation* for the reaction. And we thus see that on this basis the temperature coefficient of the specific reaction rate is related in a very simple manner to the energy of activation.

The derivation is, however, not a general one, since it contains the assumption that the rate of activation is high enough compared with the rate of reaction to maintain sensibly the full Maxwell-Boltzmann quota of molecules in the activated states.

To treat the general case in which the rate of activation is not necessarily high compared with the rate of reaction is more difficult. The treatment is possible, however, and leads to an expression[9] for $d \log k/dt$ which contains further terms in addition to $(\overline{\overline{\varepsilon}}_a - \overline{\varepsilon}_i)/kT^2$. These added terms, however, are apparently small, so that the temperature coefficient when large appears to be mainly due to the energy of activation as given by equation (8).

I wish to emphasize the desirability of retaining the name *energy of activation* or *heat of activation* for the quantity $\overline{\overline{E}}_a - \overline{E}_i$ which on the *average* is the energy that has to be supplied to the molecules that react. In the first place, this definition dates back at least to 1920.[10] In the second place, the heats of reaction of ordinary thermochemistry are determined by the difference in the average energy of the molecules of the products and the molecules of the original reactant. In the third place, when we come to consider possible mechanisms of activation, we shall be specially interested in the energy on the average that has to be supplied to the molecules that react. In the fourth place, the quantity $\overline{\overline{E}}_a - \overline{E}_i$ in accordance with equation (8) and the more elaborate deduction mentioned, appears to be the quantity which determines at least the major part of the large temperature coefficients met in practice. And finally, in accordance with equation (8), the quantity $\overline{\overline{E}}_a - \overline{E}_i$ is apparenlty the one actually calculated from experimental observations of the temperature coefficient of reaction rate.

For these reasons, I do not think it wise to adopt a recent proposal[11] to redefine the energy of activation as the minimum energy which a molecule ever has when it reacts. I know at present no experimental method of determining this latter quantity; the quantity would bear no simple relation to the temperature coefficient of the reaction; and is not of primary interest in connection with the serious problem which we must next consider as to the mechanism by which molecules obtain the average energy $\overline{\overline{E}}_a - \overline{E}_i$ per mol which is necessary in order for the reaction to proceed.

[9] See TOLMAN, *Jour. Amer. Chem. Soc.*, **47**, 2652 (1925).
[10] See TOLMAN, *Jour. Amer. Chem. Soc.*, **42**, 2506 (1920).
[11] See LEWIS and SMITH, *Jour. Amer. Chem. Soc.*, **47**, 1515 (1925).

(10) *The Mechanism of Activation.*—We must now turn our attention to this difficult question of the mechanism of activation. To put it specifically, how do the nitrogen pentoxide molecules that decompose obtain on the average 24,700 calories per mol? At the very least we must find some way to activate the molecules as fast as they are found experimentally to decompose. Four major proposals as to the mechanism of activation have been made.

The simplest proposal is that the molecules are activated by collision with other molecules. Assuming, however, a diameter as large as 10^{-7} cm. and assuming activation for every collision in which the available kinetic energy is as great as 24,700 calories per mol, we find by calculation that the rate of activation would only be 1/10,000 as fast as the known rate of decomposition of nitrogen pentoxide, and hence may at once dismiss this possibility.

A second proposal is that molecules of reactant are activated by collisions of the second kind with activated molecules of the product of the reaction, the supply of activated molecules of the original reactant thus being maintained at the full Maxwell-Boltzmann quota. It is difficult, however, to believe that this proposal could account for the decomposition of nitrogen pentoxide. In the first place the rate of decomposition of nitrogen pentoxide remains unchanged when foreign substances are present to such an extent that the activated molecules of product would make thousands of collisions with other molecules before ever coming in contact with a nitrogen pentoxide molecule. And in the second place, the decomposition of nitrogen pentoxide is endothermic, so that the molecules of product in falling to their normal unactivated states would not give up sufficient energy at least completely to activate the nitrogen pentoxide.

A third proposal is the simple radiation theory, which assumes that the process of activation consists in picking up a quantum of energy from the thermal radiation present of the frequency ν given by the simple quantum theory relation

$$\varepsilon_{\text{activation}} = h\nu . \qquad (9)$$

This must be abandoned, however, for three reasons. In the first place, nitrogen pentoxide does not absorb radiation of the frequency so calculated. In the second place, nitrogen pentoxide has been subjected to radiation of this frequency from an external

source and does not then decompose any faster. And in the third place, theory and experiment both indicate in general that the rates of absorption of radiation would in general be too small, considering the small amount of thermal radiation present, to activate molecules fast enough to account for known rates of unimolecular reaction; too small indeed by a factor of the order of 1,000,000.

There is a fourth proposal for which I like to use the term "elaborated radiation theory." Equation (9) assumes a single normal and a single activated state, and hence that only a single frequency is active. The general nature of quantum phenomena, however, indicates that we must expect a number of quantum states of various energy contents and perhaps a very large number of states, sufficiently activated for reaction, with energy levels lying close together. And in addition the facts of photochemistry show us that a large range of frequencies will usually lead to chemical reaction. Hence it seems at least barely possible that an elaborated radiation theory might account for the mechanism of activation. The failure of nitrogen pentoxide to respond to the frequency predicted by equation (9) could be explained by the possibility that the final activational step consisted in a jump from an intermediate state of activation to a final state having sufficient energy to decompose. And the rate of activation *might* possibly be large enough to account for known rates of reaction, if the jump to a very large number of different activated states could lead to reaction.

I can only say that I do not think that the elaborated radiation theory has yet been proved by experiment to be untenable. We are now making experiments on this theory in the Gates Chemical Laboratory. It would not surprise me, however, if the elaborated radiation theory also had to be given up or greatly modified.

(11) *The Mechanism of Energy Transfer between Molecules.*—We are, you see, in a very difficult situation and the way out is not clear. The Arrhenius picture of chemical reaction leads to large heats of activation and we have the greatest difficulty in accounting for the high rates at which this energy must be supplied to the molecules that react. Perhaps the picture must be given up, a possibility which has been very wisely urged by Doctor Wulf, of the Gates Chemical Laboratory. We have, nevertheless, as yet nothing satisfactory to substitute.

I must also call your attention, however, to other cases in

which it is very difficult to account for the rate at which energy is supplied to molecules, cases in which the energy is not a hypothetical heat of activation, but a very definitely known quantity.

A very interesting example of the difficulty is furnished by the famous Stern and Gerlach experiment on the orientation of silver atoms in a magnetic field. In this experiment a ray of vaporized silver atoms is shot between the poles of a strong magnet, the atoms remaining in the magnetic field only for a time of the order of 10^{-4} seconds. Nevertheless, in this short time interval all the atoms orient themselves so that their own magnetic axis is parallel to the field, and most remarkable of all, approximately half the atoms turn in the direction of lining up with the field and the other half in the *opposite* direction. Hence half the atoms receive energy at a rate far greater than we can account for on the basis of any known mechanisms of energy transfer.

A similar difficulty is possible in the case of the decomposition of nitrogen tetroxide to form the dioxide. This reaction appears from experiments on the velocity of sound through a mixture of the two gases to take place at a rate so fast as not to be measurable.[12] Hence, here too, we must inquire into the mechanism by which the tetroxide molecules acquire energy fast enough, since they are found to dissociate more quickly than they could receive the necessary energy by collision. It is to be specially noted in this case, moreover, that here we are dealing not with a hypothetical energy of activation, but with the known energy necessary for the dissociation of the tetroxide molecule.

These examples of the difficulties in other cases of accounting for the rapidity with which energy is received by atoms or molecules may indicate the necessity of a fundamental modification in our ideas as to the conservation or transfer of energy. Two possibilities would seem to be open.

First, we might give up the conservation of energy, except as a statistical principle. Then we should never have to inquire where the energy comes from when a molecule is excited, but should merely have to balance our energy account in the long run. In the case of the Stern and Gerlach experiment, since approximately half the silver atoms receive energy and the other half lose

[12] GRUNEISEN and GOENS, *Ann. der Phys.*, **72**, 193 (1923).

it, this balance is immediately made. In the case of the passage of sound waves through a mixture of nitrogen tetroxide and dioxide, the balance is made at the end of every complete period of the wave. And finally, to balance our account in the case of chemical reactions taking place through activation, we should not have to supply the whole calculated energy of activation but only the much smaller positive or negative energy actually necessary for the reaction itself, since in endothermic reactions most of the energy of activation is immediately again made available by the deactivation of the products, and in exothermic reactions there is even energy to spare.

A second possibility would be always to assume the conservation of energy even for individual molecular processes, but to postulate when necessary a very special coupling by which energy disappearing from one molecule could reappear in another. Thus in the Stern and Gerlach experiment, every silver atom that turned with the field would be "coupled" with one which turned against the field and supply to it the necessary energy. In the passage of a sound wave through the mixture of tetroxide and dioxide, each molecule of tetroxide dissociating in a region of low pressure could receive its energy from a molecule recombining in a region of high pressure. And in the case of chemical reactions taking place through activation, a molecule to be activated would draw its supply directly from that made available by the completion of the reaction undergone by some other molecule. Such immediate transfers, however, would of course take place in ways not now known to us. Perhaps they would involve molecular diameters much larger than those made familiar by the kinetic theory, a possibility which has been suggested by Doctor Wulf, of the Gates Chemical Laboratory, in connection with the work of Data [13] which seemed to indicate unusual diameters.

Of course it may not be necessary to introduce hypotheses of such a kind in order to preserve the Arrhenius hypothesis of chemical reaction through activation. On the other hand, it must of course be emphasized that the Arrhenius picture itself may be wrong. These are among the most important questions for the future of chemistry.

[13] DATA, *Zeitschr. für Phys.*, **37**, 625 (1926).

THE SENSITIVITY OF SILVER HALIDE GRAINS IN RELATION TO SIZE.*

BY

S. E. SHEPPARD AND A. P. H. TRIVELLI.

In a number of microscopic investigations on the grain size of emulsions by different investigators,[1] it was shown that in one and the same emulsion the photographic sensitivity increased with size of grain. The relation of sensitivity to grain size (projective area) was statistical in character, in the sense that not every large grain was more sensitive than every smaller grain, but on an average there was a steady increase in sensitivity with grain size in the same emulsion. The conclusion that grain size directly affects photographic sensitivity was subsequently queried by F. F. Renwick and his collaborators.[2] They found, by an ingenious method of sedimentation analysis, that for the emulsions investigated the larger grains had a higher content of silver iodide than the smaller ones of the same emulsion. A typical set of their data illustrating this is given in Table I.

TABLE I.

Layer.	Percentage AgI.	Relative Speed.
A	4.34	110
B	3.56	80
C	3.44	88
D	2.92	78
E	1.82	16
Original	3.20	65

By a process of centrifugal fractionation developed in this laboratory other high-speed silver iodo-bromide emulsions were first mechanically separated and then analyzed. The results in general confirmed Renwick's finding. Thus the original average

* Communication No. 298 from the Research Laboratory of the Eastman Kodak Company.

[1] TH. SVEDBERG, *Zeit. Wiss. Phot.*, **20**, p. 36 (1920). F. C. TOY, *Phot. J.*, **45**, p. 471 (1921). S. E. SHEPPARD and E. P. WIGHTMAN, *J. Phys. Chem.*, **25**, pp. 181, 561 (1921).

[2] "Colloid Symposium Monograph," Vol. II, p. 37; *Phot. J.*, p. 360 (1924).

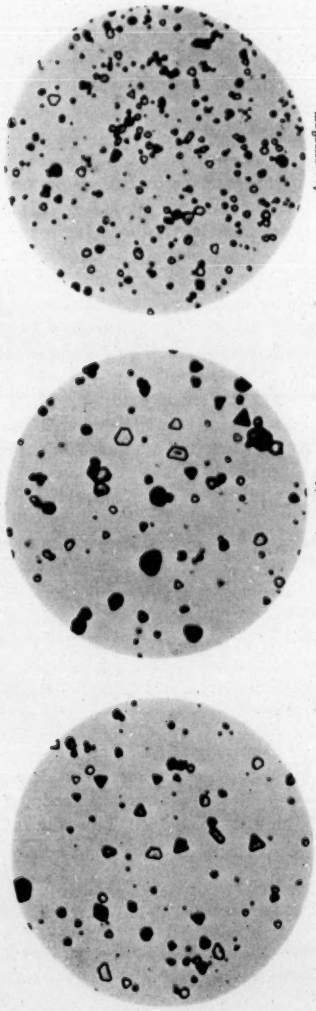


FIG. 1.

*A*1—residue.
Equal weight of Ag-halide on each plate.
Centrifuged emulsion M 265-36 × 2500.

*A*2—overflow.

O—original.

percentage was 5.8 AgI, the large grain portion gave 7.0 per cent. AgI, the fine grain portion 2.7 per cent. AgI. The figures show

FIG. 2.

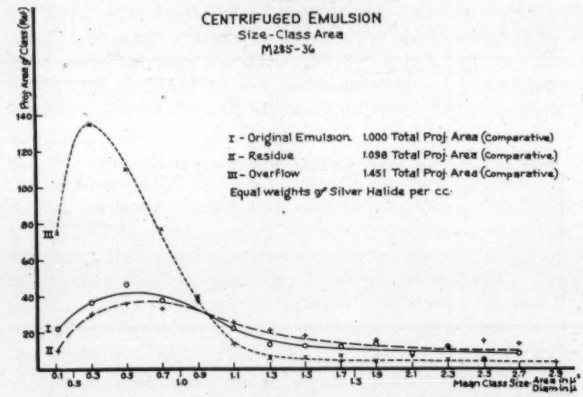
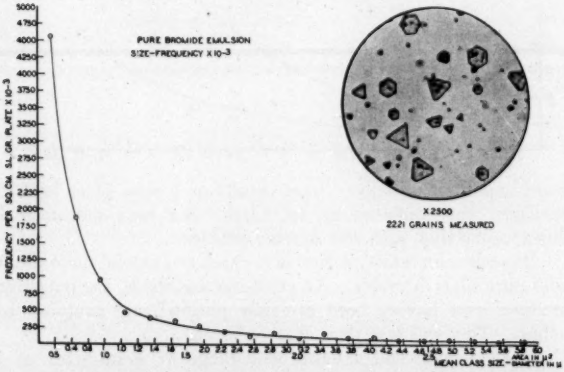

CENTRIFUGED EMULSION
Size-Class Area
M285-36
Proj Area of Class (%o)
I - Original Emulsion 1.000 Total Proj Area (Comparative)
II - Residue 1.098 Total Proj Area (Comparative)
III - Overflow 1.451 Total Proj Area (Comparative)
Equal weights of Silver Halide per cc.
Mean Class Size-Area in μ²
Diam in μ

FIG. 3.


PURE BROMIDE EMULSION
SIZE-FREQUENCY X 10-3
FREQUENCY PER SQ CM. SL. GR. PLATE X 10-3
X 2500
2221 GRAINS MEASURED
MEAN CLASS SIZE-DIAMETER IN μ
AREA IN μ²

the type of emulsion and the separation effected. (Figs. 1 and 2.)

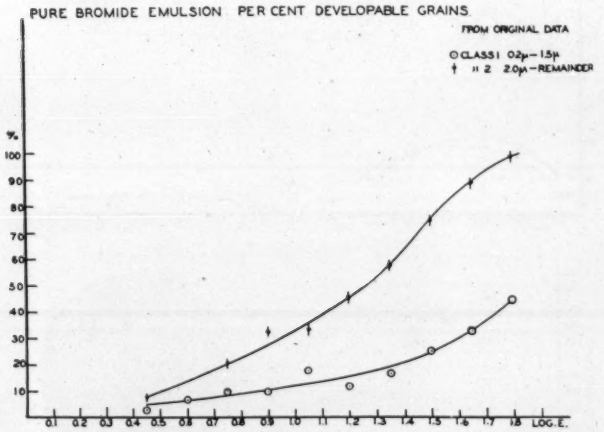
Renwick and his collaborators [3] have extended their work on

[3] W. D. BALDSIEFEN, V. B. SEASE, and F. F. RENWICK, *Phot. J.*, **66**, p. 163 (1926).

the influence of iodide in silver halide emulsions. While the results confirm the importance of silver iodide content, they do not add material information on the question of grain size, their most important bearing being on the intermixture and interaction of silver iodide and silver bromide.

It is evident that a first step in dealing with the issue raised by Renwick is to determine grain-size sensitivity in pure silver bromide and iodide emulsions separately, the former being the

FIG. 4.



more important initially. Some results on a pure silver bromide emulsion were reported by W. Clark,[4] but were not made in direct connection with this specific problem.

It seemed, therefore, desirable to check and extend these results with pure silver bromide. An emulsion was made, the potassium bromide used having been carefully purified and analyzed for iodine. This was less than .002 per cent.

The emulsion had a quite wide range of grain sizes, as is shown by the size-frequency curve and photomicrograph (Fig. 3).

In view of other considerations to be noted, the trial of sensitivity was at first limited to two broad classes: (I) The fine

[4] *Phot. J.*, **66**, 80 (1926).

grains from .2 μ to 1.5 μ diameter and (II) the coarse grains 2 μ upward. The percentage numbers made developable by different exposures are shown in the figure. (Fig. 4.)

While these results show that greater proportion of iodide is not a necessary condition for relative greater sensitivity of large grains, they do not give any indication as to the reason. In the case of α-particles, large grains appear to be inherently more sensitive as a purely statistical effect of projective area or target size.[5] In the case of light, where the presence of sensitizing nuclei is much more important than for α-particles or X-rays,[6] the relative sensitivity of grains of different size requires study in relation to the formation and disposition of sensitivity nuclei. It may be that any size-sensitivity effect is conditioned solely by the chance of a grain of given size requiring a sensitizing speck of a certain size,[7] or there may be a residual size effect similar to that with α-particles and X-rays. A study of the effect of sensitizing pure silver bromide emulsions is being made in relation to this.

[5] TH. SVEDBERG, *Phot. J.*, **62**, pp. 180, 310 (1922).
[6] S. E. SHEPPARD and A. P. H. TRIVELLI, *Phot. J.*, **66**, p. 505 (1926).
[7] *Cf.* S. E. SHEPPARD, *Phot. J.*, **65**, p. 330 (1925).

Simple Method of Determining Oil Content of Flaxseed. (U. S. Department of Agriculture, Press Service.)—A simple method for testing flaxseed and linseed cake to determine the oil content of these products has been developed by the Chemical Research Laboratory of the Bureau of Agricultural Economics.

Laboratory research has shown a wide variation to exist in the oil content of the various qualities and classes of foreign- and domestic-grown flaxseed. Extensive tests have been made of the flaxseed crops for the years 1919–1924, inclusive, the result of which has been the development of a method of testing which in fifteen minutes gives correct oil content.

Details of the department's study, together with a description of the test method recommended, have been published in U. S. Department of Agriculture Department Bulletin 1471-D, entitled "Oil Content of Flaxseed, with Comparisons of Tests for Determining Oil Content."

The bulletin deals with the production and consumption of flaxseed in the United States, world production and trade in flaxseed, oil content of flaxseed by classes, physical tests for determining oil content, inspection and grading of flaxseed, relation between numerical grade of domestic flaxseed and oil content of the sample, and a simple, rapid test for determining oil content.

Acetylsalicylic Acid.—T. S. CARSWELL (*Jour. Am. Pharm. Asso.*, 1927, **16**, 306–309) has made a study of the factors which influence the melting-point of acetylsalicylic acid or aspirin. This compound melts with decomposition. The melting-point varies somewhat according to the solvent (chloroform, benzene, acetone, ethyl alcohol) used for its crystallization. This phenomenon is ascribed to differences in the physical structure of the crystals. However, when the crystals are ground to 200 mesh, a uniform melting-point is obtained. The nearest approach to the true melting-point is 135.0° C. ± 0.2°; this value is obtained when the finely ground sample is inserted into a bath previously heated to a temperature of 125° C., and is then heated so that the temperature increases at the rate of exactly 5° per minute. J. S. H.

Physiological Significance of Glucosone.—Glucosone is ketoglucose with the formula $CH_2OH.CHOH.CHOH.CHOH.CO.CHO$. It has been of interest to the organic chemist, and has been of great value in performing certain syntheses in the sugar group. Recent work of ALEXANDER HYND, of the University of Saint Andrews (*Proc. Roy. Soc.*, Series B, 1927, **101**, 244–262), indicates that glucosone is an important compound in the metabolism of carbohydrates, being produced from the glucose of the blood by the action of insulin. It possibly also has a part in the final stage of the metabolism of fats. J. S. H.

A CONTRIBUTION TO THE CHEMISTRY OF THE EDIBLE DOMESTIC BIRDS.

BY

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WHILE an extensive literature, both European and American, exists on the biochemistry of the common fowl, *Gallus domesticus*, comparatively little work has been done in either hemisphere on the biochemistry of the other domestic edible birds, such as the turkey, the goose, and the duck.

The present study has been devoted primarily to the determination of the constants of the visceral fat of the turkey and the goose, the subcutaneous fat of the goose, and the egg fat of the duck and the goose. Determination has also been made of the gross composition of the crude visceral fat, and of the eggs of the respective species enumerated.

The crude visceral fat is the adipose connective tissue which occurs in the abdomen and surrounds the gizzard. It was obtained from freshly killed birds, one turkey, *Meleagris gallopavo*, and one goose, *Anser anser*. The subcutaneous fat is the fat which occurs in the subcutaneous fascia. The eggs, goose and duck, were freshly laid and fertile.

PREPARATION OF SAMPLES.

The crude visceral fat was ground by repeated passage through a meat grinder. A portion was taken for determination of the gross composition, including crude protein, ether extract, and moisture. The remainder of the crude fat was extracted in a Soxhlet apparatus, using petroleum ether, Benzinum Purificatum, U.S.P.X,[1] as the solvent. Heat was supplied by an electric hot plate. The period of extraction was sixteen hours. The extract was filtered, if necessary; and the filtrate was evaporated at a temperature of 100° C. The extracted fat was used for the determination of the fat constants.

The subcutaneous fascia was not dissected from the skin.

The skin and adherent fascia were ground and extracted with petroleum ether in the manner just described, in order to obtain the subcutaneous fat for determination of the fat constants.

With the eggs of each species, determination was made of the weight of the whole egg, its distribution between shell and edible portion, and the relative masses of the white and yolk. The whites and the yolks were separated by the procedure described by Hepburn [2] for hen eggs. The vitelline membrane of both duck eggs and goose eggs appeared to have a greater tensile strength than that of hen eggs when subjected to this procedure. The shells and the yolks were actually weighed. The weights of the edible portion and of the whites were determined by difference. Portions of the white, the yolk, and the whole egg (mixed white and yolk) of each species were used for the determination of their gross composition, after rendering each sample homogeneous by means of an electric stirrer. The remainders of the yolk and of the whole egg were dried by heating at a temperature of 100° C., then were extracted with petroleum ether, in the manner described above, in order to obtain the yolk fat for determination of its constants.

ANALYTIC METHODS.

The methods of analysis were essentially those of the Association of Official Agricultural Chemists.[3] Total solids and moisture were determined by drying at 100° C. to constant weight; fat or ether extract was determined by extraction of the solids with ethyl ether in an electrically heated Knorr apparatus. Ash was determined by incineration in a gas-heated muffle furnace. For the determination of crude protein, use was made of the Gunning modification of the Kjeldahl method, and the protein factor 6.25. The iodine number of the fat was determined by the official Hanus method, and also by the Hübl method as described by Lewkowitsch.[4] The soluble acids have been calculated as per cent. of butyric acid. The index of refraction of the fat was determined by means of the Spencer refractometer. In order to determine the phosphorus in the fat, which is a measure of its lecithin content, from 2 to 10 grams of the fat were digested with concentrated sulphuric acid and potassium nitrate to destroy the organic compounds; the phosphorus was precipitated as ammonium phosphomolybdate, and was finally

weighed as magnesium pyrophosphate. The dextrose content of the eggs was determined by the colorimetric method of Hepburn and St. John,[5] which is an application to egg analysis of the method of Folin and Wu[6] for the determination of dextrose in blood.

GOOSE EGGS.

Seven individual eggs of the goose, *Anser anser,* were weighed. The maximum weight was 174.5 grams; the minimum weight, 111.0 grams; the average weight, 133.0 grams. In these seven eggs, the shell formed 12.72 per cent. and the edible portion 87.28 per cent. of the gross weight. In four of the eggs, the yolk formed 36.86 per cent. and the white 63.14 per cent. by weight of the edible portion.

DUCK EGGS.

Six individual eggs of the duck, *Anas erythrorhynchos,* were weighed. The maximum weight was 88.0 grams; the minimum weight, 75.0 grams; the average weight, 80.3 grams. In these six eggs, the shell formed 10.58 per cent., and the edible portion 89.42 per cent. of the gross weight. In three of the eggs, the yolk formed 38.08 per cent., and the white 61.92 per cent. by weight of the edible portion.

CHEMICAL COMPOSITION OF THE EGGS.

Analyses of the eggs of the duck and the goose have been published by Langworthy,[7] Camaille,[8] and König.[9]

The results of our analysis of eggs have been collected in Table I. The "whole egg" of this table is the total edible portion or mixed white and yolk. Each series of analyses was made on a composite sample of three eggs. Thus the "whole egg" was obtained from three eggs; and the "white" and the "yolk" were separated from another set of three eggs. The calories reported are large or kilogram calories. The caloric values were calculated from the percentage composition, 1 gram of fat yielding 9.3 calories, and 1 gram of either carbohydrate or protein yielding 4.1 calories.

The duck eggs and the goose eggs, analyzed in this research, came from farms in the vicinity of Philadelphia. The hennery eggs, studied by Pennington,[10] and by Jenkins, Hepburn, Swan and Sherwood,[11] were likewise derived from farms in the vicinity of Philadelphia. It is of interest to compare the eggs of the

three species with respect to their chemical composition and nutrient value.

The whites of the three species show no marked differences in composition. The yolks of both duck eggs and goose eggs contain a higher percentage of total solids, ether extract, and

TABLE I.

Gross Composition of Eggs.

		Duck.			Goose.		
		Whole Egg.	White.	Yolk.	Whole Egg.	White.	Yolk.
Total solids, per cent.		31.45	12.98	56.31	38.75	12.08	58.90
Moisture, per cent.		68.55	87.02	43.69	71.25	87.92	41.10
Ether extract, per cent.		14.36	0.01	35.04	12.20	0.06	35.74
Crude protein, per cent.		13.64	9.88	18.42	14.12	10.77	18.67
Ash, per cent.		0.82	0.21	1.35	1.17	0.68	1.73
Dextrose, per cent.		0.18	0.55	0.23	0.40	0.52	0.12
Calories per 100 grams	Fat	133.5	0.1	325.9	113.5	0.6	332.4
	Protein	55.9	40.3	75.5	57.9	44.2	76.5
	Carbohydrate	0.7	2.3	0.9	1.6	2.1	0.5
	Total	190.1	42.7	402.3	173.0	46.9	409.4

crude protein than do hen eggs; as may be seen on comparison of the figures for these constituents in Table I, with the following average values for the yolks of fresh hennery eggs as given by the authors just cited:

	Yolks of Infertile White Leghorn Eggs. (Per Cent.)	Yolks of Fertile Barred Plymouth Rock Eggs. (Per Cent.)
Total solids	52.57	51.97
Ether extract	32.65	32.70
Crude protein	17.44	16.75

In consequence of this higher content of fat (ether extract) and protein, a given mass of yolk of goose egg or duck egg has a greater nutrient value than the same mass of yolk of hen egg.

COMPOSITION OF THE ABDOMINAL ADIPOSE CONNECTIVE TISSUE.

The chemical composition of the abdominal adipose connective tissue of the turkey and the goose apparently has not been studied by previous investigators. A research on the enzymes of this tissue in the turkey has been published by Hepburn.[12]

The results of our analyses are given in Table II. As might be expected from the histological structure of adipose tissue,[13]

TABLE II.

Composition of the Abdominal Adipose Connective Tissue.

	Turkey.	Goose.
Total solids, per cent.	92.94	91.46
Moisture, per cent.	7.06	8.54
Ether extract, per cent.	90.20	88.12
Crude protein, per cent.	2.24	2.57

this tissue, as it occurs in the abdominal cavity of the turkey and the goose, contains small amounts of protein and moisture, derived from the protoplasm of the connective-tissue cells, and a large amount of fat (ether extract), deposited in these cells.

FAT CONSTANTS.

Amthor and Zink [14] have reported the constants of the fat of the turkey (*Truthahn*), determined on the fat of a single bird. Ross and Race [15] and Carlin [16] have also reported the constants of this fat. These three studies were made in Continental Europe, Great Britain, and the United States, respectively. Carlin used freshly killed birds, and obtained the fat by rendering. It was semi-solid and slightly granular and had the following constants:

Specific gravity at 15°C.	0.911
Acid number	15.3
Saponification number	196.5
Congealing point, °C.	19

Amthor and Zink [14] also reported the constants of the fat of the domestic goose (*Hausgans*) obtained from two birds. They mention the work of several previous investigators on goose fat. König [17] gives the constants of goose fat (*Gänsefett*). All of the analyses apparently were made on European varieties of the domestic goose.

Carlin [16] also determined the constants of the fat of the domestic goose of the United States. The fat was obtained from freshly killed birds. The rendered fat was semi-solid and slightly granular, and had the following constants:

Specific gravity at 15°C.	0.907
Acid number	2.19
Saponification number	192.15
Melting-point, °C.	28.5
Congealing point, °C.	17.5

The constants of the fats studied in this research are given in Table III. The visceral and subcutaneous fats were semi-solid, granular, and pale yellow in color. The egg-yolk fats were unctious masses, dark reddish-yellow in color.

The results obtained by ourselves indicate that the visceral

TABLE III.

Fat Constants.

Constant.	Turkey.	Goose.			Duck.
	Visceral Fat.	Visceral Fat.	Subcutaneous Fat.	Egg-yolk Fat.	Egg-yolk Fat.
Acid value	6.8	3.4	0.5	4.7	4.8
Saponification number	225.1	211.6	216.5	199.2	205.1
Ester value	218.3	208.2	216.0	194.5	200.3
Hehner number	90.87	89.58	94.90	87.10	87.46
Iodine number (Hanus)	64.90	64.3	71.4	63.0	77.3
Iodine number (Hübl)	65.5	68.6	73.4	63.3	70.8
Soluble acids	5.48	4.16	None	2.57	2.66
Index of refraction at 40° C.	1.4663	1.4647	1.4659	1.4651	1.4674
Phosphorus (per cent.)	0.074	0.165	0.156	0.927	0.628

fat in the freshly killed turkey, or the goose, has a higher acidity than the visceral fat of the freshly killed chicken. Pennington and Hepburn [18] found that the acid value of the visceral fat of the freshly killed chicken is less than 1, usually 0.8.

SUMMARY.

The chemical composition of the eggs of the duck and the goose has been determined, and their nutrient value has been calculated.

The chemical composition of the abdominal adipose tissue of the turkey and the goose has been reported.

The fat constants have been determined for the visceral fat of the turkey and the goose, the subcutaneous fat of the goose, and the egg-yolk fat of the goose and the duck.

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Influence of Carbon Dioxide upon Butter and Ice Cream.—Certain undesirable changes, which occur in butter and ice cream, are frequently attributed to the action of atmospheric oxygen. As a result, the suggestion has been made that the air, which is normally incorporated in these foods, be replaced by carbon dioxide. F. F. SHERWOOD and F. G. MARTIN (Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, *Research Bulletin No. 95*, 177–207, 1926) have churned and worked butter in an atmosphere of carbon dioxide, and have frozen ice cream in an atmosphere of that gas. Control samples were manufactured in the usual manner. Their extensive series of researches led to the following conclusions. Carbon dioxide did not influence the chemical composition, bacterial flora, and rate of oxidation of butter, and tended to lower its score. Carbon dioxide did not influence the quality, texture, standing-up property, chemical composition, and bacterial count of ice cream. Neither butter nor ice cream retained appreciable quantities of carbon dioxide. J. S. H.

Natural Sodium Bicarbonate Waters.—According to W. D. COLLINS and C. S. HOWARD, of the U. S. Geological Survey (*Ind. and Eng. Chem.*, 1927, **19**, 623–624), sodium bicarbonate waters frequently occur in the Atlantic Coastal Plain which extends from southern New Jersey along the Atlantic and Gulf coasts to Mexico; these waters are almost entirely free from calcium and magnesium, and are suitable for general use. However, natural sodium bicarbonate waters do not occur in Florida. Waters of this type have not been found in New England or northern California; they have been observed in southern California and Arizona, Nevada, North Dakota, Montana, Illinois, Indiana, southern Minnesota, and other portions of the United States. In all these regions, sufficient calcium and magnesium may be present to render the water hard, and sufficient sulphates and chlorides to render it unsuitable for general use. J. S. H.

The Nation and Science.—HERBERT HOOVER (*Sigma Xi Quarterly*, 1927, **15**, 13–19) stresses the national necessity for enlarged activities in support of research in pure science, "A host of men, great equipment, long, patient scientific experiment to build up the structure of knowledge, not stone by stone, but grain by grain, is now our only sure road of discovery and invention." Yet activities in pure science have actually decreased in the United States during the past decade, partly as a result of the increased enrolment of students in the universities, partly as the result of withdrawal of research men from educational institutions to enter industrial laboratories. Support for research in pure science must come from the national and state governments, the industries, and private benevolence. J. S. H.

A SEARCH FOR THE VILLARI REVERSAL EFFECT IN NICKEL.

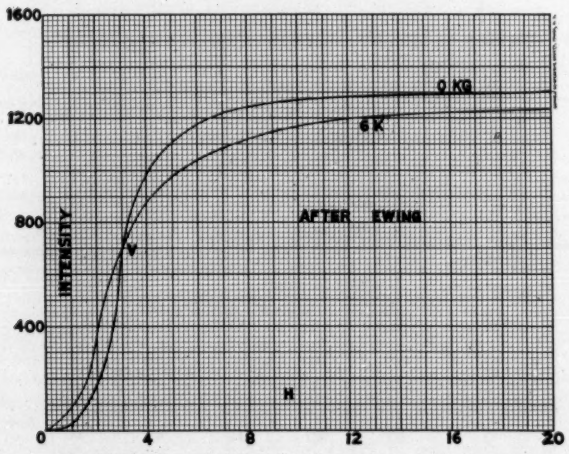
BY

S. R. WILLIAMS, Ph.D.

Department of Physics, Amherst College.

IT IS a well-substantiated fact that a longitudinal pull applied to a bar of iron increases the magnetic induction when a weak magnetic field is applied, but decreases the flux in a strong field.

FIG. 1.



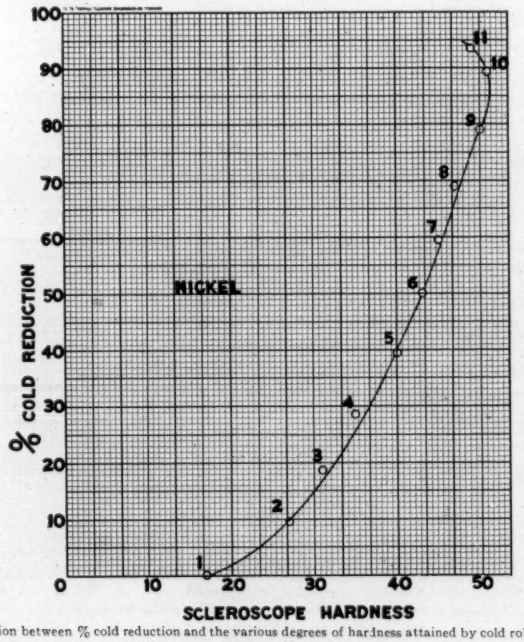
Magnetization of annealed iron under various amounts of longitudinal pull.

The intensity of magnetization for an iron rod as it is magnetized, with and without a tension of 6 kilograms, is shown in the two curves of Fig. 1, taken from Ewing's book.[1] The point of intersection of the two curves, *V*, is called the "Villari reversal point." It is the point where the effect of a tension is reversed.

Some years ago a series of polemical papers [2] discussed the question as to whether a similar effect could be found in nickel or not. The arguments were left more or less unanswered

because various mechanical and heat treatments may give a wide range of magnetostrictive effects, and it is barely possible that those finding the effect actually had some specimens which showed the reversal. Later it was shown [3] that if any extraneous magnetic fields were present these could give rise to Villari reversal

FIG. 2.



Relation between % cold reduction and the various degrees of hardness attained by cold rolling.

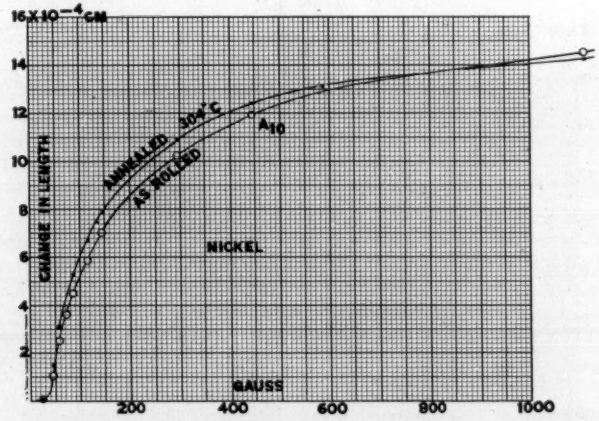
points and, furthermore, when these extraneous fields were removed the Villari reversal points also disappeared in the specimens being tested. Even this evidence against the possibility of a Villari reversal point in nickel was weak because only one kind of nickel was used.

In a recent study [4] of the hardness of a series of eleven nickel strips by magnetic methods, it was possible to study the

Joule magnetostrictive effect in varieties of nickel where variations were produced by cold rolling to successive thicknesses or to different degrees of hardness.

It has been shown [5] that the Villari effect is the reciprocal of the Joule magnetostrictive effect. If a substance has its magnetic induction decreased due to a tension, then that substance will shorten for those fields for which the magnetic induction

FIG. 3.



Effect of annealing at 304° C. for one hour.

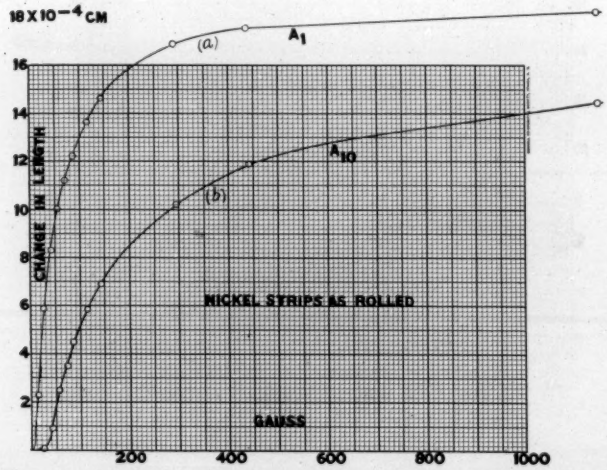
decreased due to a tension. Similarly a rod will lengthen for those magnetic fields in which tension increases the flux. The principle of Le Chatelier holds in these phenomena. Consequently if a substance shows a Villari reversal effect, it will also show a reversal of sign in the change of length as the field is increased from zero to higher values. The Joule magnetostrictive effect is, therefore, a sensitive means of indirectly studying the presence or absence of the Villari reversal effect. This was the means employed in this paper; the method for measuring the changes in length as the field was varied has been described elsewhere.[6] If nickel shows a Villari reversal effect like iron, then it will first lengthen for weak magnetic fields and shorten for strong.

Twenty-two strips of nickel were studied in this work, there

being two samples for each degree of hardness. No initial lengthening occurred as the magnetic field was increased from zero to larger values. *Shortening only occurred for all field strengths up to a value of 1200 gauss. This absence of the Villari reversal in the nickel strips with eleven different physical conditions is good evidence that the Villari reversal points thus far reported for nickel were fictitious.*

Through the courtesy of the International Nickel Company,

FIG. 4.



Decreasing the thickness of a nickel strip, 93 per cent., affects tremendously the magnetic change in length.

eleven strips of nickel were furnished which had been rolled to successive thicknesses. This cold working of the nickel gave as many degrees of hardness as there were reductions. Fig. 2 shows the relation between the per cent. cold reduction and the various degrees of hardness. The nickel was in the form of bars, 4.8 cm. wide and 0.61 cm. thick, which were then rolled to the successive degrees of thickness and hardness as shown in Fig. 2. Due to the size of the strips as rolled it was possible to cut from the centre of each strip, longitudinally, two parallel strips 0.9 cm. wide. This gave a chance to check results for each degree of cold reduc-

tion expressed in per cent. The strips as finally used were 0.9 cm. wide and 58 cm. long with thicknesses as left by rolling.

Table I gives the chemical analysis of the nickel from which the strips were rolled.

TABLE I.

Copper	0.16
Nickel	98.88
Iron	0.56
Sulphur	0.008
Silicon	0.06
Carbon	0.09
Manganese	0.23

The two sets of strips were numbered:

$A_1, A_2, A_3, A_4 \ldots\ldots\ldots\ldots A_{11}$ and

$B_1, B_2, B_3, B_4 \ldots\ldots\ldots\ldots B_{11}$, respectively. The subscripts refer to the sample numbers as given in Fig. 2.

In the cutting and shaping of these strips great care was taken not to raise the temperature of the strip more than ten or fifteen degrees centigrade, in order that as little change as possible would be produced in the physical properties of the strips. The changes in length were first measured as rolled. After annealing at 304° C. for an hour to take out local strains, the changes in length of the strips were again measured. This annealing process affected the Joule magnetostrictive effect a little as shown in Fig. 3.

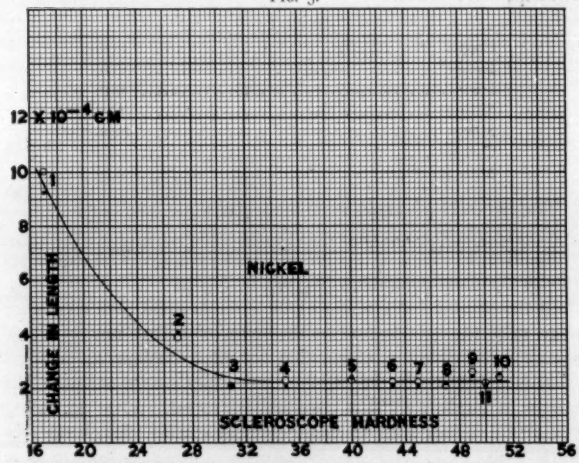
Fig. 4 shows how the change in length progressed in the strips A_1 and A_{10} as the field increased from zero up to about 1200 gauss. Curves for the other strips are not shown, since from A_3 to A_{11}, inclusive, they are practically the same as A_{10}. The values for A_{10} are shown because this strip had the highest hardness number. The similarity of the curves for the Joule effect, after the second reduction, is shown in Fig. 5, where the values are taken for the field strength of 58.88 gauss. Whatever the machinery whereby the change in length occurs, it is all reduced to the same phase after the second reduction. Fig. 5 also shows how reproducible the results are. The circles show the values of the changes in length for the A series of strips and the square dots are those for the B series. Attention is called to the close agreement between the two sets of readings.

It is unfortunate that, in controversies of the sort indicated in

this paper, others did not have an opportunity for checking the results of those finding the Villari reversal or *vice versa*.

Thus far the evidence seems to support the conclusion that in

FIG. 5.



The machinery for magnetic change in length is reduced to the same phase after the second reduction. In all cases, $H = 58.88$ gauss.

the tension-magnetization curves of nickel there are no Villari reversal points.

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ON THE PROPAGATION OF SOUND IN THE GENERAL BESSEL HORN OF INFINITE LENGTH.

A DISCUSSION.

BY

C. R. HANNA.

Westinghouse Electric and Manufacturing Company.

MR. BALLANTINE'S paper [1] is a valuable addition to the previous work on propagation of sound in horns. The author, apparently without realizing it, has obtained data which show the superiority of the exponential horn.

Bessel horns, having the shape

$$A = bx^n,$$

are considered, and it is shown that for horns of equal length and terminal areas, the low-frequency radiation may be improved by choosing n greater and greater. The conclusions, stated in the author's words are:

"The effect of increasing Bessel flaring [presumably n in the above equation, although 'flaring' is not defined by the author] is to augment the response for low notes in quite the same fashion as in the exponential horn, except that no critical frequency exists. The flaring of the horn is thus of advantage in promoting a more uniform frequency response and a better quality of conduction from throat to mouth. In view of these results the exponential horn loses a great deal of its esoteric significance. As expected, the flaring seems to be the thing."

It will here be shown that as n increases without limit, the shape of the Bessel horn approaches that of the exponential horn, and thus the significance of the exponential shape is enhanced rather than minimized by Ballantine's work. To do this, let

$$A = A_0 (ax + 1)^n,$$

so as to place the throat area at the origin.

If A_0, A_1 and l are the throat and mouth areas and the length, all of which are to be held constant as n is varied, it is seen that a will be function of n determined as follows:

[1] This JOURNAL, January, 1927, p. 85.

$$A_1 = A_0 (al + 1)^n$$

$$a = \frac{\sqrt[n]{\frac{A_1}{A_0}} - 1}{l}.$$

Hence

$$A = A_0 \left\{ \frac{\sqrt[n]{\frac{A_1}{A_0}} - 1}{l} x + 1 \right\}^n$$

is the general equation of the Bessel horn having initial and final areas A_0 and A_1 and length l.

The relative rate of increase of area with distance is:

$$\frac{1}{A}\frac{dA}{dx} = \frac{n\left\{\frac{\sqrt[n]{\frac{A_1}{A_0}} - 1}{l}\right\}}{\frac{\sqrt[n]{\frac{A_1}{A_0}} - 1}{l} x + 1}$$

$$= \frac{n}{x + \frac{l}{\sqrt[n]{\frac{A_1}{A_0}} - 1}}.$$

As n becomes very large, any finite value of x in the denominator is insignificant, and so

$$\lim_{n \to \infty} \frac{1}{A}\frac{dA}{dx} = \lim_{n \to \infty} \frac{n\left\{\left(\frac{A_1}{A_0}\right)^{1/n} - 1\right\}}{l}$$

$$= \lim_{m \to 0} \frac{\left\{\frac{A_1}{A_0}\right\}^m - 1}{lm} \quad \text{where } m = 1/n$$

$$= \lim_{m \to 0} \frac{\left\{\frac{A_1}{A_0}\right\}^m \log \frac{A_1}{A_0}}{l}$$

$$= \frac{1}{l} \log \frac{A_1}{A_0}$$

which is constant. The limiting shape then is exponential, for letting

$$\frac{1}{l}\log\frac{A_1}{A_0} = B$$

the equation of the horn which satisfies

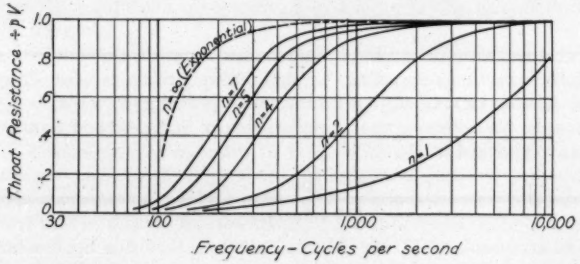
$$\frac{1}{A}\frac{dA}{dx} = B$$

and the terminal condition that when $x = 0$, $A = A_0$ is

$$A = A_0 \varepsilon^{Bx}.$$

The information given in Ballantine's Fig. 5, which shows radiation resistance against frequency for horns of a particular

FIG. 1.



size (length 200 cm., initial and final openings 1 cm. and 40 cm. in diameter, respectively) as n takes the values, 1, 2, 4, 5 and 7 may be extended to include the curve for $n = \infty$ since this is the exponential shape whose performance is already well known.[2] The set of curves with the one for the exponential horn shown dotted is here given. The superiority is evident.

In the paper referred to [2] a proof of the superiority of the exponential horn was given, but no claim as to rigor was made. The comparison of cone and exponential horns was made to substantiate the contention. The work of Ballantine, if rightly interpreted, gives further evidence of the superiority of the exponentially shaped horn.

[2] C. R. Hanna and J. Slepian, "Function and Design of Horns for Loud Speakers," *Trans. A.I.E.E.*, 1924.

REPLY BY MR. BALLANTINE.

I am much obliged to Mr. Hanna for his interest in my paper on the Bessel horn and for sending in his discussion of it, to which I should like to make the following reply.

The point which he raises as to the ultimate confluence of the Bessel horn to the shape of the exponential horn as the flaring index m of the former is illimitably increased and x remains finite, had been previously recognized by me, and can perhaps be demonstrated with less algebra directly from the differential equations for the two types. Thus:

$$\frac{\partial^2\varphi}{\partial x^2} + \frac{m}{x}\frac{\partial\varphi}{\partial x} + k^2\varphi = 0\,; \quad \text{Bessel Horn, } A = A_1x^m\,; \qquad (1)$$

$$\frac{\partial^2\varphi}{\partial x^2} + b\frac{\partial\varphi}{\partial x} + k^2\varphi = 0\,; \quad \text{Exponential Horn, } A = A_1e^{bx}. \qquad (2)$$

For given terminal areas A_2 and A_1 and length l, the value of x (called x_0) corresponding to the throat orifice is, for large m, $x_0 = lm/\log(A_2/A_1)$. If the variable is changed ($x = x_0 + x'$) so as to place the origin at the throat, m/x in the second term of (1) is changed to:

$$m \Big/ \frac{lm}{\log(A_2/A_1)} + x'. \qquad (3)$$

The argument which Mr. Hanna makes is that this approaches a constant value as $m \to \infty$ for all finite values of x'. By identifying this value with b for the exponential horn (equation 2), it is inferred that the Bessel horn may be made to approach the shape of the exponential horn for finite x by choosing m sufficiently large.

A comparison of the shapes of the horns for $m = 4$ and $m = 7$ given in Fig. 4 of my paper, and also the general crowding together of the curves of Fig. 5 as m is increased, naturally suggests the approach to some sort of limit. As a matter of fact, I had noticed this some time ago and out of curiosity had derived an expression for the throat impedance for $m = \infty$, but did not include it in my paper because I felt that the publication of the mere formula was useless in view of the fact that I did not have the patience to make the somewhat tedious computations from it for Fig. 5. I had merely noticed that the curve would resemble that

of the exponential horn (see Mr. Hanna's drawing) at the top, but would depart from it somewhat at the bottom because there were no discontinuities in the Bessel functions. The precise form of this limiting function may be derived from the asymptotic expressions for the Bessel functions of large order and argument which have been obtained by Rayleigh [3] and Macdonald [4] by applying Kelvin's principle of stationary phase. In our case:

$$H^{(2)}{}_n(z) \sim \sqrt{\frac{2}{\pi z}} \frac{\exp - i\left[z \sin \vartheta - n\vartheta - \frac{1}{4}\pi\right]}{\sqrt{\sin \vartheta}}.$$

$$\vartheta = \cos^{-1} \frac{n}{z}$$

The computations from these formulæ are especially awkward for the conditions contemplated in Fig. 5 in the neighborhood of 100 cycles.

My own early conclusions are thus in substantial agreement with those expressed by Mr. Hanna. I was not anxious to include them in my paper because it was not my intention to criticize the exponential horn one way or the other, but hoped merely to show, by examining a new family of horns with adjustable flaring, that the curvature of the flaring was the important factor in improving the transmission of low notes with a constant velocity source, and that in this respect the shape of the exponential horn was not unique. On account of the mathematical difficulties connected with the theoretical treatment of horns of all possible shapes, it was my hope that the physical picture thus presented might be of some practical value.

[3] *Scientific Papers*, **5**, 620.

[4] *Phil. Trans. Roy. Soc.*, **210**, 31.

The Energy of the Struck String. W. H. GEORGE and H. E. BECKETT. (*Proc. Roy. Soc.*, A 766.)—In bowed musical instruments as well as in wind instruments energy is imparted about as long as the sound lasts. On the other hand, in the case of the piano the transfer of energy takes place in a small fraction of a second preceding the emission of sound. In the evolution of the piano by empirical methods its sounds, at first too weak and of too brief duration, have been improved by the device of means to increase the initial energy of the vibrating system. It is interesting to learn how untramelled by theory the development of the instrument has been, for the authors say, "In the literature of the subject we have been unable to find any references to theoretical or experimental work on the energy of the struck string."

A metal cylinder with a sharp edge, swinging on a bifilar suspension, struck a horizontally stretched wire and rebounded. Its positions before falling and at the end of the rebound were determined by projecting its shadow on a scale. The energy due to the displacement of the cylinder from its position with the supporting threads vertical gets to be distributed thus: (*a*) In the rebound, (*b*) in vibrations produced in the struck string, (*c*) in vibrations in the hammer and its suspension, (*d*) in permanent deformation of hammer and struck string, (*e*) in friction losses. In this paper, chiefly the first is measured. Hammers of different mass in relation to the mass of the struck wire were made to strike the wire at different places.

For light hammers, *i.e.*, for those in which the ratio of their effective mass to the mass of the wire between the bridges is less than .4, the energy lost by the impact grows rapidly as the point struck removes from the vicinity of the bridge and attains a maximum value which it preserves over some distance of further approach to the middle of the wire. There is a rapid increase in the quantity of lost energy as the point of contact nears the middle. When the above ratio is .5 instead of .4, there is a sharp maximum, and, as the ratio is increased, the position of the maximum loss of energy moves nearer to the bridge and the loss itself becomes less. An especially important relation is the following, "The maximum fraction of the hammer's initial energy lost during the impact decreases continuously with increase in the mass of the hammer, but the absolute value of the energy lost increases continuously with increase in the mass of the hammer." G. F. S.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE DUPLICATION OF MOTION PICTURE NEGATIVES.[1]

By J. G. Capstaff and M. W. Seymour.

A FILM suitable for making duplicate negatives should have higher resolving power than motion picture negative in order to keep graininess at a minimum. It should have lower maximum contrast than motion picture positive in order to permit complete development and thus to avoid the development defects which accompany incomplete development. By adding a water-soluble yellow dye to a fine-grained emulsion, the Eastman Kodak Company has produced a suitable film. By reason of the dye, the film has high resolving power, great latitude, and the possibility of giving different degrees of contrast when different color filters are used in the light beam of the printer. Since the speed is only about 1/20 that of positive film, more light than usual is necessary in the printer. A curved gate in the printer is recommended to insure good contact. By accurately timing the master positive, a duplicate negative may be made that requires no light changes in printing. The proper use of Eastman Duplicating Film for both master positive and duplicate negative insures excellent reproduction of the tones of the original negative, freedom from development defects, and a minimum of graininess.

* Communicated by the Director.

[1] Communication No. 294 from the Research Laboratories of the Eastman Kodak Company and published in *Trans. Soc. Mot. Pict. Eng.*, No. 28, 1926, p. 223; *Amer. Cinemat.*, **7**, 9 *et seq.*, 1926 (Dec.); *Amer. Phot.*, **21**, 78, 1927; *Kinotechnik*, **8**, 617, 1926.

An Apparatus for Producing Rotation by the Use of Sound Waves. G. HIPPE. (*Ann. d. Phys.*, No. 2, 1927.)—A horizontal wooden rod turns in a horizontal plane about a steel axis passing through its middle. At one extremity of the rod is an ordinary telephone diaphragm, forming one end of an air chamber of cylindrical form, the second end of which is closed by sheet metal except for an orifice. This opening has a mouthpiece of stream-line form which favors the development of the force producing rotation. The axis of the air chamber is horizontal and is perpendicular to the length of the wooden rod. There is a movable counterpoise on the other end of the rod.

By two contacts rotating in circular mercury troughs an alternating current flows through the telephone coils, its strength being some hundredths of an ampere. To secure rotation the frequency of the current must be such as to produce the loudest possible tone. This comes when the tone emitted lies between the characteristic tone of the membrane and that of the resonator. When the pitch is right a strong current of air issues from the orifice of the resonator, which blows out a candle a few centimetres away. The telephone receiver and the counterpoise together weigh three-quarters of a kilogram and the apparatus is of such size as to serve for demonstration before an audience. The success of the device in causing motion by the reaction of sound waves depends upon the source of sound being contained in the apparatus. Measurements gave a force equal to the weight of 10 grams or even more as developed when rotation took place. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN VAPOR PRESSURE. III. THE TOLUIDINES.[1]

By J. F. T. Berliner and O. E. May.

[ABSTRACT.]

THE vapor pressures of the three isomeric toluidines have been determined from about 40° to a few degrees above their normal boiling-points. The normal boiling-points found were as follows: o-toluidine, 199.84°; m-toluidine, 202.86°; p-toluidine, 200.35°.

The vapor-pressure equations have been calculated and the equations for the heats of vaporization derived therefrom. The calculated values from the vapor-pressure equations agree well with the observed values and the heats of vaporization vary linearly with the temperature.

The entropies of vaporization at a vapor-phase concentration of 0.00507 mole per litre indicate that the toluidines are somewhat highly associated substances.

STUDIES IN VAPOR PRESSURE. IV. THE NAPHTHOLS.[2]

By O. E. May, J. F. T. Berliner and D. F. J. Lynch.

[ABSTRACT.]

THE vapor pressures of α-naphthol and β-naphthol have been determined from temperatures a few degrees above their melting-points to temperatures a few degrees above their boiling-points. Their boiling-points at atmospheric pressure were found to be 288.01° and 294.85°, respectively.

The latent-heat equations have been derived, and the calculated and observed results correspond closely.

The entropies of vaporization of the naphthols at a concentration of 0.00507 mole per litre have been calculated. They indicate that the naphthols do not form normal liquids.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, **49**, April, 1927, pp. 1007–1011.

[2] Published in *J. Am. Chem. Soc.*, **49**, April, 1927, pp. 1012–1016.

CLERGET-INVERTASE HYDROLYSIS CONSTANTS OF SUCROSE AND RAFFINOSE.[3]

By H. S. Paine and R. T. Balch.

[ABSTRACT.]

THE Clerget-invertase hydrolysis constant of sucrose was determined. The relation between sucrose concentration and this constant is expressed by the equation, constant = 131.17 + 0.073 *c*, where *c* is the number of g. of sucrose in 100 c.c.

The value 0.521, which shows negligible variation over a considerable range of concentration, was found for the ratio of polarization of raffinose after invertase hydrolysis to the original polarization. These values are applicable in enzymic analytical methods for the determination of sucrose and of sucrose and raffinose in mixture.

AUTOMATIC DEVICES FOR THE EXTRACTION OF POWDERED MATERIALS.[4]

By S. Palkin and H. R. Watkins.

[ABSTRACT.]

Two automatic devices for the extraction of solid substances, particularly plant drugs, are described. One is an inexpensive, simple device, in which the extracting solvent is made to flow rapidly *upward* through the sample and is continuously filtered through a cotton filter device back into the heating vessel. Absence of a thimble and the upward flow of solvent keeps the powdered material loosely suspended. The circulation principle causes the solvent to flow through the whole mass of sample evenly with no stagnant central cores, as might be the case where a thimble is employed. The same extractor vessel or jacket may also be used for the liquid extractors previously described.

The other device, somewhat more complex, makes use of the pressure effect of the solvent vapors to produce continuous agitation of the suspended sample. Continuous filtration is effected in the same way that it is in the simple form. This apparatus is applicable to the extraction of liquids as well.

[3] Published in *J. Am. Chem. Soc.*, **49**, April, 1927, pp. 1019–1028.

[4] Published in *Ind. Eng. Chem.*, **19**, April, 1927, pp. 535–537.

NOTES FROM THE U. S. BUREAU OF MINES.*

RECOVERY OF MOLYBDITE FROM THE ORE.

By H. A. Doerner.

In 1914 the bureau investigated molybdenum resources of this country, and the results of that investigation were published in Bulletin 111. More recently, the bureau has studied the utilization of molybdite. It was found that many molybdenite deposits contain a considerable amount of oxidized molybdenum. Recovery of this oxidized content is an urgent, unsolved problem. No mechanical methods of concentration have been effective in extracting the oxidized molybdenum. Dielectric separation is an undeveloped method which seems to have very limited possibilities.

Two leaching methods have been carefully tested and seem to have commercial possibilities: (1) Extract the ore with hot soda solution, acidify with sulphuric acid, add a small amount of sodium acetate, and digest with lead sulphate. Molybdenum is completely precipitated as $PbMoO_4$, which can be converted to MoO_3. (2) Extract the ore with warm, dilute sulphuric acid and completely neutralize the free acid with scrap iron. Molybdenum is completely precipitated as a hydrate of MoO_2, nearly pure.

By treating the hot roasted ore with chlorine practically complete separation of the molybdenum from all other ore constituents is obtained in one operation. The distillate is quite pure and is easily converted to MoO_3 or $CaMoO_4$. The consumption of chlorine need not be heavy and the regeneration of chlorine for repeated use seems possible. Further details will be found in Technical Paper 399, recently published by the Bureau of Mines.

BOWIE-GAVIN PROCESS, CRACKING OF TARS AND HEAVY OILS.

By C. P. Bowie.

A process and an apparatus have been designed, as the result of extensive experimental work done by the bureau, for cracking tars and heavy oils which will be utilized to eke out the waning production from wells. This process can be used to recover oil

* Communicated by the Director.

from oil shale and oil-soaked sands, and the authors believe that when the necessary economies in its operation are worked out the process can be applied to cracking asphalts, still bottoms, and similar heavy residuals at refineries. The details of the process are given in Technical Paper 370 of the Bureau of Mines, lately issued.

BENEFICIATION AND UTILIZATION OF GEORGIA CLAYS.

By R. T. Stull and G. A. Bole.

UNDER a coöperative agreement between the Bureau of Mines and the Central of Georgia Railway, the resources of ceramic raw materials of the coastal plain within Georgia were carefully examined by a field survey, and thirty samples of about one ton each of the various clays selected for test were taken.

After preliminary elutriation tests, an experimental washing plant, with approximately three to five tons daily capacity, was built at Columbus. Two men were employed continuously for two years on the work. Commercial trials were made at eleven plants.

This work was divided into six parts as follows: (1) Occurrence of the clays tested; (2) washing tests; (3) physical tests; (4) utilization of kaolins in white ware; (5) utilization of clays in refractories; and (6) utilization of clays in face brick. In brief, the conclusions are as follows:

The State of Georgia contains a large area of sedimentary kaolins and bauxites of industrial importance. Considerable development has taken place, and many undeveloped deposits are available. The working properties and fire tests of the crude clays are mostly from fair to good. The color numbers range from 1 to 10, and average nearly 4. In the screen tests of the crude materials the range through 150 mesh was 46.15 to 99.89 per

Range of Composition of Clays.

	Crude Clay.	Washed Clay.
	Per cent.	Per cent.
Ignition loss	11.92–25.89	12.25–19.09
Silica	14.08–50.81	32.35–45.76
Alumina	33.61–56.23	35.13–46.06
Iron	.44– 1.92	.54– 1.56
Titania	.77– 2.34	.88– 1.72
Sulphur	.01– .16	.01– .18

cent., but if the lowest results, which were bauxite clays, be eliminated the range was 82.11 to 99.89 per cent. The washed clays showed a range of recovery of 70.40 to 82.18 per cent. in the filter presses. Chemical analyses showed the above part range of composition.

If Georgia clays are mined, refined, and blended with care, they can be used more in white ware than they are now. The high bisque loss and shrinkage can be overcome by proper body mixes and blending of clays. Georgia clays can be used to some extent in place of English china clay in floor and wall tile. Furnace tests under actual working conditions have proved that the service rendered by fire brick made from Georgia sedimentary kaolins was superior to that rendered by fire clay. Light gray face brick can be made from a mixture of Georgia kaolin, aplite, and sand. A more complete description of the tests is presented in Mines Bulletin 252.

The Gases Contained in Brasses, in Aluminum and in Its Alloys. L. GUILLET and A. ROUX. (*Comptes Rendus,* March 21, 1927.)—Two specimens of brass were examined. They were melted in crucibles, rolled and then drawn in the usual industrial manner. An hour was spent in raising their temperature to 720° C., at which temperature they were maintained for two hours. The gas given off during the entire time was collected and measured. In the comparisons made below, the volume of gas was reduced to 0° and 76 cm. pressure. For brass of composition Cu 67 per cent., Zn 33 per cent., the evolved gas had .55 of the volume of the metal, while for the other kind, having composition Cu 60 per cent., Zn 40 per cent., the ratio is .39 only. Analysis of the gases gave these results by volume:

	CO_2 %	CO %	H %	CH^4 %	N %
Brass (Cu 67%, Zn 33%).....	14.16	13.6	65.4	0	7.4
Brass (Cu 60%, Zn 40%).....	8.6	0	56.4	0	43.6

In spite of the manifest error in the percentages for the first specimen these figures are of considerable interest. The gases began to come off at 480° and ceased to appear by the close of the operation.

In another test a specimen of brass whose composition is not stated was heated until it melted. The evolution of gas commenced at 530°, showed a maximum rate between 720° and 790° and a second maximum more important than the first between 930° and 980°. The total volume of gas amounted to .5 of that of the metal. Its composition was CO_2 19 per cent., CO 9.5 per cent., H 35.9 per cent., CH^4 22.2 per cent., N 13.4 per cent.

In the case of aluminum containing .6 per cent. of iron and silicon the evolved gas had only .14 of the volume of the metal. It was made up thus—CO_2 20 per cent., CO 12 per cent., H 68 per cent. and N 0 per cent. The gas given off by duralumin had .23 of the volume of the metal and contained 91 per cent. of hydrogen. G. F. S.

New Series of One-color Indicators.—The one-color indicators at present in use, for example phenolphthalein, are colorless in acid solution and colored in alkaline solution. I. M. KALTHOFF, of the University of Utrecht (*Jour. Am. Chem. Soc.,* 1927, **49,** 1218–1221), finds that several derivatives of triphenylcarbinol, containing 5, 6, or 7 methoxy groups, are excellent indicators which are colorless in alkaline solution and colored in acid solution. J. S. H.

Phosphorus Pentafluoride.—HOWARD J. LUCAS and FRED J. EWING, of the California Institute of Technology (*Jour. Am. Chem. Soc.,* 1927, **49,** 1270), have devised a new procedure for the preparation of phosphorus pentafluoride. Calcium fluoride is dried by heating, and is then mixed with highest grade phosphorus pentoxide in an iron pipe which is capped at one end. The mixture is then heated. Phosphorus pentafluoride is evolved as a gas which fumes in moist air. The product contains approximately 94 per cent. phosphorus pentafluoride; the remainder is hydrogen fluoride which is formed as a result of the presence of traces of moisture. J. S. H.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting Held Wednesday, May 18, 1927.)

THE stated monthly meeting of the Institute, at which the exercises in celebration of Medal Day were held, was called to order at three-forty-five by President Wm. C. L. Eglin.

The President stated that the minutes of the April meeting had been printed in full in the May number of the JOURNAL and that unless there were objection, they would be approved as printed. No objection was offered and the minutes were declared approved as printed.

The President then called upon the Secretary, Dr. Howard McClenahan, who stated that he had two announcements to make, of especial interest to the members. He reported: "Mr. President, I wish to make two announcements which should be of interest to the members of the Institute. In the first place, Prof. W. F. G. Swann, head of the Department of Physics, Yale University, has been invited to become the head of the Bartol Research Foundation and has accepted the invitation. Professor Swann will take up his active work in connection with our Laboratories on September first, next. It is needless to say that his appointment brings with it promise of very great achievement to the Laboratories, because Professor Swann is one of the leading physicists and research men of the United States."

This announcement was received with enthusiastic applause, and the Institute was congratulated upon its good fortune by the other scientists present.

The Secretary continued: "The other matter of which I should like to make mention is one that has been noted recently in the daily papers—the fact that the Institute hopes to build upon the Parkway a great museum of science, technology and industry, which shall be a monument to the industrial accomplishments of the business men and the scientists of Philadelphia, and a most effective addition to the agencies for the teaching of science throughout this city. The museum, if the City Council will look upon our request favorably, will be located on the Parkway, between Eighteenth and Nineteenth Streets, will be in its purpose chiefly educational, and will be, we firmly believe, a very distinguished monument to science and its accomplishments in Philadelphia, and an instrument which will bring great credit to this institute. As our plans develop, the members will be fully informed of what we are doing and of the things which we hope to accomplish."

The President then announced that the awarding of Medals was the next order of business, and stated that all the medals which have been recommended during the present Institute year by the Committee on Science and the Arts would be presented at this time. The exercises in connection with the presentation of the various medals were then held.

PROGRAMME.

Presentation of Longstreth Medals to	Sponsor:
MR. WILFRED LEWIS	Mr. Coleman Sellers, III
Tabor Manufacturing Company	

MR. HARRY W. HARDINGE Hardinge Company Represented by Mr. Harlowe Hardinge	Mr. F. V. Hetzel
MR. JAMES F. SMATHERS Smathers Power Typewriting Company	Mr. C. W. Bates
Presentation of the Wetherill Medal to NORTH EAST APPLIANCES INC. With special mention of Mr. Russell G. Thompson	Mr. C. W. Bates
Presentation of the Levy Medal to WILLIAM DAVID COOLIDGE, PH.D. General Electric Company	Mr. Benj. Franklin
Presentation of Potts Medals to GEORGE EARLE BEGGS, C.E. Associate Professor of Civil Engineering, Princeton University	Mr. Benj. Franklin
COMMANDER MARION EPPLEY, U.S.N.-R.F., PH.D. Eppley Scientific Laboratories	Mr. C. A. Hall
Presentation of Cresson Medals to EDWARD LEAMINGTON NICHOLS, PH.D., D.Sc., LL.D. Professor Emeritus of Physics, Cornell University	Prof. W. R. Wright
DAYTON CLARENCE MILLER, D.Sc. Research Professor of Physics, Case School of Applied Science	Prof. T. D. Cope
Presentation of the Franklin Medal and Certificate of Honorary Membership to PROFESSOR MAX PLANCK, PH.D. University of Berlin Received by the Counselor of Embassy, Dr. O. C. Kiep The German Embassy, Washington, D. C.	Dr. James Barnes
Presentation of the Franklin Medal and Certificate of Honorary Membership to GEORGE ELLERY HALE, PH.D., D.Sc., LL.D. Honorary Director, Mt. Wilson Observatory Received by Harlow Shapley, Ph.D., Professor of Astronomy and Director of Harvard College Observatory, Harvard University	Dr. James Barnes

PAPERS

"The Physical Reality of Light-quanta," by PROFESSOR MAX PLANCK. Presented by PROFESSOR T. D. COPE, University of Pennsylvania.

"The Sun as a Research Laboratory," by DR. GEORGE ELLERY HALE. Presented by PROFESSOR HARLOW SHAPLEY, Harvard University.

Adjourned.

HOWARD MCCLENAHAN,
Secretary.

(An extended account of the proceedings of this Medal Day meeting will appear in the July number of the JOURNAL.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting Held Wednesday, May 4, 1927.)

HALL OF THE COMMITTEE,
PHILADELPHIA, May 4, 1927.

MR. M. M. PRICE *in the Chair.*

The following reports were presented for final action:

No. 2847: Hardinge Air Classifier.

The chief functions of this device are to classify the ground material coming from a Hardinge or other type of tube mill, to deliver a more uniformly sized product to the collector and to return to the mill, for regrinding, all over-size material above a certain degree of fineness.

This material is returned by means of a stream of air entering the mill at the delivery end and travelling in the opposite direction to the stream of air that is passing through the mill, thus depositing it at or near the feed end of the mill and preventing clogging.

The award of the Edward Longstreth Medal to Mr. Harry W. Hardinge, of New York City, N. Y., was recommended for this device.

No. 2858: Thurlow Backwater Suppressor.

The purpose of this device is to overcome the loss of power that results from the reduction of the effective head of water due to the excess flow over the spillway under flood conditions.

Water flowing over the face of a dam having an ogee section, leaves the apron with high velocity and sets up at a point below the dam a standing backwater wave, that cuts down the effective head and produces the anomalous result that when the feed water is above the normal height, the power output is below the normal. Briefly, this invention consists in making use of energy of the spillway water by directing it over the orifices of the turbine draft tubes in such a way as to remove the standing wave and increase the effective head on the turbines.

The award of the Howard N. Potts Medal to Mr. Oscar G. Thurlow, of Birmingham, Ala., was recommended for this improvement.

No. 2869: The Eppley Standard Cell.

This report considers the improvements that have been made in the standard cadmium cell for the purpose of producing a cell of low-temperature coefficient and of unvarying electromotive force.

The outstanding improvements made in this cell are: Increasing the accuracy by using an acid instead of a neutral electrolyte, regulating the grain size to control the constancy of the electromotive force, and developing a rigorous technic in the manufacture of the cell that has resulted in the production of cells of the highest quality and in any desired quantity.

This report recommends the award of the Howard N. Potts Medal to Dr. Marion Eppley, of Newport, R. I.

No. 2870: Work of Dr. Edward L. Nichols.

This report recommended the award of the Elliott Cresson Medal to Dr. Edward Leamington Nichols, of Ithaca, N. Y., "in consideration of his achievements as an investigator, and, in particular, of his services to the development of the science of physics in this country."

The following report was presented for first reading:

No. 2868: Filmo Camera and Projector.

GEORGE A. HOADLEY,
Secretary, S. and A. Committee.

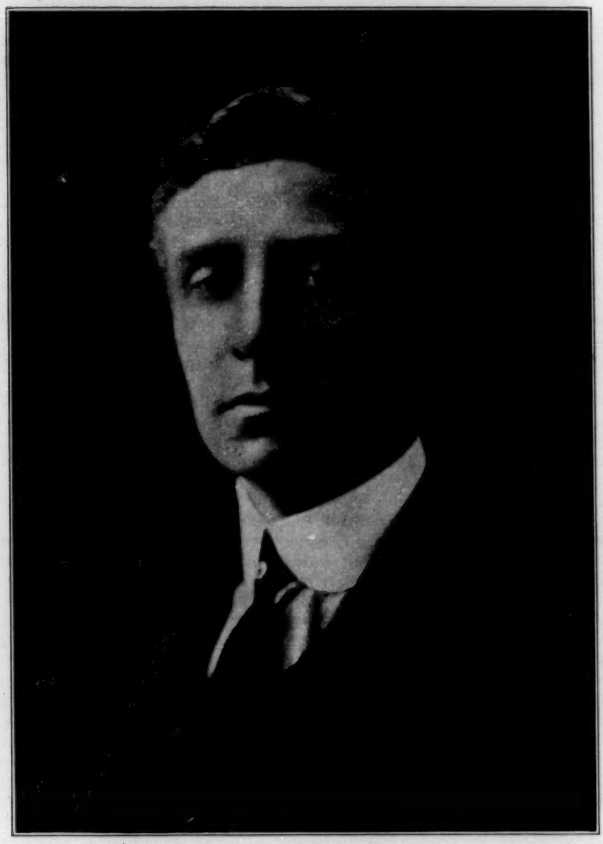
BARTOL RESEARCH FOUNDATION.

APPOINTMENT OF DIRECTOR.

DR. W. F. G. SWANN, Professor of Physics and Director of the Sloane Laboratory, Yale University, has accepted the invitation of The Franklin Institute to become the Director of the Bartol Research Foundation of the Institute, and will assume the duties of his office in September next.

Professor Swann was born in England, was educated in the English schools and in the University of London, by which institution he was made Doctor of Science. He came to America in 1913, in order to take the position of Chief of the Physical Division, the Department of Terrestrial Magnetism of the Carnegie Institution in Washington. He was subsequently Professor of Physics at the University of Minnesota, and the University of Chicago, and has been at Yale since 1924. He is a Fellow of the Physical Society of London, a member of the British A.A.S., and the A.A.A.S., the American Philosophical Society, the American Physical Society, the Optical Society, the Washington Academy of Sciences, the National Research Council, The Franklin Institute, Gamma Alpha, Sigma Xi.

Doctor Swann is one of the leading research men in physics in the United States; he has produced many articles on modern physical developments, either directly or through graduate students working under his care. He is a lecturer of compelling charm and is much sought after for the public platform. At Yale he has been head of the research work carried on so effectively in the Sloane Physics Laboratory. During the last year and a half Professor Swann and Prof. E. P. Adams, of Princeton, have been in charge of the research work carried on at the Bartol Research Foundation Laboratories at Nineteenth and Cherry Streets, where, during the present year, six Fellows have been engaged on full time in research work.



DR. W. F. G. SWANN
Director, Bartol Research Laboratories.

In the summer of 1925, Doctor Swann made a trip to Norway, and in the summer of 1926 made a trip to Pike's Peak, Colo., under the auspices of the Bartol Foundation, in order to make an experimental search for radiations of cosmic origin. The results of his two trips appeared in the JOURNAL OF THE FRANKLIN INSTITUTE.

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

DR. RAYMOND F. BACON, 271 Madison Avenue, New York City, N. Y.
MR. J. C. BANNISTER, University Club, 76 East Monroe Street, Chicago, Ill.
MR. J. V. BOSTWICK, Haverford, Penna.
MR. JAMES M. CAIRD, Cannon Building, Broadway and Second Street, Troy, N. Y.
MR. A. J. B. HARRIS, Winthrop-Beach Hotel, 6241 Winthrop Avenue, Chicago, Ill.
MR. N. G. HERRESHOFF, 6 Walley Street, Bristol, R. I.
MR. CHARLES F. KELLERS, 204 Steward Avenue, Jackson, Mich.
MR. EDGAR C. B. KIRSOPP, 222 West Washington Square, Philadelphia, Penna.
MR. DANIEL O. LANDIS, 48 Fairview Avenue, Sellersville, Penna.
MAJOR C. W. MCMEEKIN, 2218 Roosevelt Avenue, Berkeley, Calif.
MR. WILLIAM C. MELCHER, JR., care of Pelton Water Wheel Company, 100 Broadway, New York City, N. Y.
MR. EUGENE MERZ, The Heller and Merz Company, 503 Hudson Street, New York City, N. Y.
MR. BENJAMIN WILEY SANDS, 1307 N Street, N.W., Washington, D. C.
MR. CHARLES E. SARGENT, 222 South Eighteenth Street, Allentown, Penna.
MR. ARTHUR SYNNESTVEDT, 1015 Chestnut Street, Philadelphia, Penna.
MR. J. T. WALLIS, Assistant Vice-president, Broad Street Station, Philadelphia, Penna.

NECROLOGY.

Mr. George R. Green, Philadelphia Electric Company, 1000 Chestnut Street, Philadelphia, Penna.

LIBRARY NOTES.

RECENT ADDITIONS.

BIGGAR, E. B.—Hydro-electric Development in Ontario. 1920.
BOUTHILLON, LÉON.—La Théorie et la Pratique des Radiocommunications. Volume 3, Part 1. 1925.
CHAMBERLAIN, JOSEPH S., Editor.—Chemistry in Agriculture. 1926.
CLARK, DAVID.—Field Astronomy for Engineers and Surveyors. 1926.
Encyclopædia Britannica. Three new supplemental volumes. 1926.
Engineering Index 1926. 1927.
EXLEY, THOMAS.—Principles of Natural Philosophy: or a New Theory of Physics. 1829.

FARRELL, HUGH.—What Price Progress? The Stake of the Investor in the Discoveries of Science. 1926.

GRANIER, JEAN.—Mesures Électriques. 1927.

HALE, GEORGE ELLERY.—Beyond the Milky Way. 1926.

HALE, GEORGE ELLERY.—The Depths of the Universe. 1924.

HALE, GEORGE ELLERY.—The New Heavens. 1923.

HOLLEY, O. L.—The Life of Benjamin Franklin. 1856.

HOWE, H. E., Editor.—Chemistry in Industry. Volume 2. 1925.

München, Das deutsche Museum. Geschichte—Aufgaben—Ziele. Bearbeitet von Conrad Matschoss. 1925.

National Telephone Exchange Association.—Proceedings of First to Fourth and Sixth Meetings. Five volumes. 1881–1884.

PARKER, H. W.—Library Classification and Numbering System. Third edition. 1926.

SAUNDERS, VIVIAN T.—The Polarimeter: A Lecture on the Theory and Practice of Polarimetry. No date.

Scientific Papers of William Parsons, Third Earl of Rosse, 1800–1867. Collected and republished by the Hon. Sir Charles Parsons. 1920.

THOMSON, SIR WILLIAM, and Others.—Answers to Ten Questions Regarding the Commercial Use of Electricity in Electric Lighting. No date.

TWYMAN, F.—Two Lectures on the Development and Present Position of Chemical Analysis by Emission Spectra. No date.

BOOK REVIEWS.

SURFACE EQUILIBRIA OF BIOLOGICAL AND ORGANIC COLLOIDS. By P. Lecomte du Noüy, D.Sc., with introductions by Alexis Carrel and Robert A. Millikan. American Chemical Society Monograph Series. 212 pages, illustrations, 8vo. New York, Chemical Catalog Company, Inc., 1926. Price, $4.50.

This treatise is devoted to a study of surface tension and surface equilibria as determined by means of the tensiometer or surface tension apparatus. In 1923, The Franklin Institute awarded the Certificate of Merit to Doctor du Noüy for this apparatus in consideration of its novelty and the ingenuity of its construction resulting in a device by means of which surface tension can be measured accurately and quickly with a very small volume of liquid. The introduction by Doctor Carrel points out the bearing of measurements of this type upon biological problems, while that by Doctor Millikan is written from the viewpoint of the student of molecular physics. The major portion of the treatise is devoted to studies of sodium oleate, egg albumin, serum constituents, immune sera, and colloidal solutions. A modified tensiometer for the measurement of the interfacial tension at the surface of separation of two liquids is also described, and results obtained with it are presented. Thirty tables give in concise form the values obtained with these instruments. In addition to copious references to the original literature as footnotes, a bibliography of eight pages is appended to the book. This treatise is a most welcome addition to scientific literature. The new method for the rapid and accurate measurement of surface tension opens new paths of attack for numerous problems in both the physical and the biological sciences. JOSEPH S. HEPBURN.

DIE SELTENEN ERDEN VOM STANDPUNKTE DES ATOMBAUES. By G. v. Hevesy, University of Frieburg in Br. Paper bound, viii–140 pages, 8vo. Berlin, Julius Springer, 1927. Price, 9 marks.

Although the basic purpose of this essay is to correlate the Bohr theory of atomic structure with the properties and relations of the group of so-called "rare earths," much information is given as to practical chemistry of them. For many chemists the theoretical considerations will be perhaps too abstruse, but to most of those who are interested in mineral chemistry the chapter on the methods of separation will be acceptable. The decision as to what is a rare element is influenced by conditions. Helium when first named was supposed to exist only in the sun, but while not now really abundant, is fairly familiar. So the cerium and thorium groups were at one time classed as very rare, but their mineral sources are now mined in large amount. It would be a great boon to chemistry if platinum could be obtained in quantity sufficient to bring its price down well below that of gold. The affection of a certain class of society for the metal would suddenly cease and chemists would benefit thereby. Rarity is, however, not the sole character that binds together the elements that are comprised in this book. The series has definite relation in properties and constitutes a special group in the periodic table and a sequence in the atomic numbers. Gadolin in 1794 was the first to recognize a member of the group by his discovery of yttria. One very interesting and instructive development of the work in the field was Welsbach's separation of didymium into two elements of contrasting color in compounds. It was mere coincidence that Mosander gave the original name meaning "twin."

Illinium is mentioned in the series, but lutecium is represented by cassiopeum (Cp), a name now not used in English books. The symbol for thulium is given as "Tu," though "Tm" is the generally accepted form.

This book is one of a series on the "Structure of Matter." The field that it covers is in the more abstruse field of chemistry, but the author has brought together a large amount of useful information. HENRY LEFFMANN.

PRINCIPES DE L'ÉLECTROCHIMIE. Par J. Ponsinet, Ingénieur des Manufactures de l'État. 211 pages, 11 × 16 cm., paper. Paris, Librairie Armand Colin, 1927. Price, unbound, 9 francs; bound, 10.25 francs.

The phenomena of electrochemistry have assumed, since their discovery not more than a hundred years ago, a great importance alike from the theoretical and the industrial points of view. In theory, the capital fact that electricity, like matter, exists in atomic form, is disclosed by electrochemical phenomena. In practice, electrochemistry has been the cradle of already large and still growing industries.

In this small volume the author has set forth with clarity and precision the experimental facts and deductive processes by which the laws of electrochemistry have been established. Ionic dissociation is employed as the basis of deduction. That method of interpreting the experimental facts he points out has the advantage of harmonizing with modern theories of matter.

The chapter headings are: The laws of electrolysis; The mechanism of electrolysis; Ions; Conductibility of electrolytes; Properties of ions; Electro-

motive force in electrochemical phenomena; Hydrogen-ion concentration; Applications of electrochemistry. A short bibliography follows in which the entries "Elements d'électricité" by Ch. Fabry and "Les méthodes actuelles de la chimie" by P. Jolibois of the same series are mentioned as suitable texts for preparatory reading. Hydrogen-ion concentration is covered in considerable detail and that chapter will be welcomed by those who seek a brief but rational account of that timely subject. The classified brief description of numerous applications in the last chapter and the principles which they employ is helpful in illustrating the possibilities of the theoretical matter of the previous chapters. On that particular side of the subject the author promises a companion volume.

The work should prove of value to readers who desire a brief account of the development of the subject by rational methods.

LUCIEN E. PICOLET.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 253, Flow and Drag Formulas for Simple Quadrics. By A. F. Zahm. 23 pages, illustrations, quarto. Washington, Government Printing Office, 1927. Price, ten cents.

In this text are given the pressure distribution and resistance found by theory and experiment for simple quadrics fixed in an infinite uniform stream of practically incompressible fluid. The experimental values pertain to air and some liquids, especially water; the theoretical refer sometimes to perfect, again to viscid fluids. For the cases treated the concordance of theory and measurement is so close as to make a résumé of results desirable. Incidentally formulas for the velocity at all points of the flow field are given, some being new forms for ready use derived in a previous paper and given in Tables I and III. A summary is given on page 22.

The present text is a slightly revised and extended form of Report No. 312, prepared by the writer for the Bureau of Aeronautics in June, 1926, and by it released for publication by the National Advisory Committee for Aeronautics. A list of symbols follows the text.

Report No. 256, The Air Forces on a Systematic Series of Biplane and Triplane Cellule Models. By Max M. Munk. 37 pages, illustrations, quarto. Washington, Government Printing Office, 1927. Price, fifteen cents.

The air forces on the largest systematic series of biplane and triplane cellule models ever published, measured in the atmospheric density tunnel of the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics, are the subject of this report. The tests consist in the determination of the lift, drag, and moment of each individual airfoil in each cellule, mostly with the same wing-section.

The magnitude of the gap and of the stagger is systematically varied; not, however, the decalage, which is zero throughout the tests. Certain check tests with a second wing-section make the tests more complete, and the conclusions more convincing.

The results give evidence that the present army and navy specifications for the relative lifts of biplanes are good. They furnish material for improv-

ing such specifications for the relative lifts of triplanes. A large number of factors can now be prescribed to take care of different cases.

Report No. 258, Some Factors Affecting the Reproducibility of Penetration and the Cut-off of Oil Sprays for Fuel-injection Engines. By E. G. Beardsley. 10 pages, illustrations, quarto. Washington, Government Printing Office, 1927. Price, five cents.

This investigation was undertaken at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics, in connection with a general research on fuel-injection engines for aircraft. The purpose of the investigation was to determine the factors controlling the reproducibility of spray penetration and secondary discharges after cut-off.

The development of single sprays from automatic injection valves was recorded by means of special high-speed photographic apparatus capable of taking 25 consecutive pictures of the moving spray at a rate of 4000 per second. The effects of two types of injection valves, injection-wave tube length, initial pressure in the injection-valve tube, speed of the injection control mechanism, and time of spray cut-off, on the reproducibility of spray penetration, and on secondary discharges were investigated.

It was found that neither type of injection valve materially affected spray reproducibility. The initial pressure in the injection-valve tube controlled the reproducibility of spray penetrations. An increase in the initial pressure or in the length of the injection-valve tube slightly increased the spray penetration within the limits of this investigation. The speed of the injection-control mechanism did not affect the penetration.

Analysis of the results indicates that secondary discharges were caused in this apparatus by pressure waves initiated by the rapid opening of the cut-off valve. The secondary discharges were eliminated in this investigation by increasing the length of the injection-valve tube.

PUBLICATIONS RECEIVED.

Collected Papers of Sir James Dewar. Edited by Lady Dewar with the assistance of J. D. Hamilton Dickson, H. Munro Ross, and E. C. Scott Dickson, with two supplementary papers not heretofore published and an appendix and indexes. Two volumes, illustrations, plates, portrait, quarto. Cambridge, University Press; New York, The Macmillan Company, 1927.

Die seltenen Erden vom Standpunkte des Atombaues, von Dr. Georg v. Hevesy. 140 pages, illustrations, 8vo. Berlin, Julius Springer, 1927. Price, in paper, nine marks.

Principes de l'Électrochimie, par J. Ponsinet. Collection Armand Colin. 215 pages, illustrations, 12mo. Paris, Armand Colin, 1927. Price, nine francs.

Eminent Chemists of Our Time, by Benjamin Harrow. Second edition, enlarged. 471 pages, illustrations, portraits, 8vo. New York, D. Van Nostrand Company, 1927. Price, $3.

The Essentials of Transformer Practice, Theory, Design and Operation, by Emerson G. Reed. Second edition, revised and enlarged. 401 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1927. Price, $5.

Electric Switch and Controlling Gear. A handbook on the design, manufacture, and use of switchgear and switchboards in central stations, factories and mines, by Charles C. Garrard. Third edition, revised and enlarged. New York, D. Van Nostrand Company, 1927. Price, $18.

National Research Council. Bulletin No. 57, Molecular Spectra in Gases, Report of the Committee on Radiation in Gases. 358 pages, illustrations, plates, 8vo. Washington, National Research Council, 1926. Price, in paper, $4.

University of Toronto Engineering Society. Transactions and Year-book. 137 pages, illustrations, portraits, 8vo. Toronto, Society, 1927.

Illinois State Water Survey. Bulletin No. 22, Investigations of Chemical Reactions Involved in Water Purification, 1920–1925. 133 pages, illustrations, 8vo. Urbana, Survey, 1926.

Achema Jahrbuch Jahrgang, 1926–1927. Berichte über den Stand und Entwickelung des chemischen Apparatewesens. Herausgegeben unter Mitwirkung von Fachgenossen aus Wissenschaft und Technik von Dr. Max Buchner. 318 pages, illustrations, 8vo. Berlin, Verlag Chemie G. m. b. H., 1927. Price, ten marks.

CURRENT TOPICS.

An Investigation into the Nature and Occurrence of the Auroral Green Line λ 5577 Å. J. C. McLennan, J. H. McLeod and W. C. McQuarrie. (*Proc. Roy. Soc.*, A 766.)—When the spectrum of the aurora is formed, this line is the most prominent. It is the strongest line also in the spectrum of the light of the night sky, as the present Lord Rayleigh has shown. The Norwegian physicist, Vegard, attributed its origin to the luminescence of finely divided solid nitrogen suspended in the upper air. His experimental results, however, fail to carry conviction. McLennan and Shrum two years ago obtained this line by sending an electric discharge through a tube containing a mixture of oxygen and helium or a mixture of oxygen and neon. The wave-length of their line was just that of the line in the light of the night sky. They even got the line, though faintly, from a discharge through oxygen alone at low pressure. The present paper is a continuation of the previous investigation.

The discharge tube, made of fused silica, was a metre in length and sealed-in windows rendered it possible to observe the light of the positive column longitudinally. Since the origin of the green line was in question, it was highly important to know the kind of gas in the discharge tube and to avoid impurities. The oxygen used was accordingly rigidly purified. Particular care was taken, by applying liquid air and otherwise, to avoid the introduction of mercury vapor and vapor from grease at the taps. With all precautions taken, the green line made its appearance on every spectrogram taken with pure oxygen in the tube, provided both the time of exposure and the current strength were adequate. The strength of the line, however, varied greatly. By photographing the line obtained from different pressures of oxygen and measuring the plates on a Moll microphotometer, it was found that the greatest strength of the line was produced by oxygen at a pressure of 2 mm. of mercury. Even so its intensity is by no means impressive after an exposure of nine hours. An increase of current strength was always accompanied by strengthening of the line. Altogether as many as a score of spectrograms attested the derivation of the line from pure oxygen.

On some of the plates two lines appeared that originated in the impurities, mercury and hydrogen. It is very unlikely that the green line comes from mercury. This was made even less probable by studying the change in intensity of the line with change of gas pressure, as was done also for the green line. The two lines were not at all alike in their changes. Since hydrogen is considered to be a constituent of the region of the atmosphere from which the light of the aurora comes, it was important to investigate the hydrogen line

appearing on the plates with the green line. With the gas pressure in the tube above 2 mm. this hydrogen line was entirely without trace, but the green line was present. The best proof of lack of connection between the two lines came from exhausting the discharge tube thoroughly, driving gas out of the electrodes and then filling with pure hydrogen. The spectrum then produced by the electrical discharge contained no indication of line 5577. Helium was added to enhance the lines, but still the green line failed to appear. These observations prove that hydrogen is not the source of the auroral line.

When any one of the gases, helium, neon or argon, is added to the oxygen in the discharge tube the green line appears with increased intensity. This is especially true for argon. Its addition makes the auroral line much stronger than before and, further, greatly enhances its strength in comparison with other oxygen lines. "It will be recalled that while it is now generally accepted that a number of the bands that appear in the auroral spectrum originate in nitrogen, the green line, which is the strongest in the auroral spectrum, is the only line in this spectrum that has as yet been assigned to oxygen. It may be that in the upper atmosphere the conditions are such as to intensify the line λ5577.35 Å. still more than we have been able to do with argon, and to entirely suppress the spectral lines of oxygen that we ordinarily observe."

When the current was sent through pure oxygen or through this gas mixed with neon, argon or helium, the green line was rarely visible from the very start. This may mean that some time is needed for the oxygen to get into the state capable of emitting the auroral line. G. F. S.

Biography of James Blythe Rogers.—EDGAR F. SMITH has added to his long list of monographs on American chemists, a brochure on James Blythe Rogers, 1802–1852. James B. Rogers was the eldest of the four Rogers brothers, each of whom became noted as a chemist or a geologist. Educated at the College of William and Mary and the medical school of the University of Maryland, he engaged in work in industrial chemistry in Maryland, served as chemist to the geological surveys of Virginia and Pennsylvania, and as a member of the faculty, in succession, in the following institutions: Washington Medical College, Maryland; Maryland Institute, University of Cincinnati, The Franklin Institute, Franklin Medical College, and University of Pennsylvania. He succeeded Robert Hare in the chair of chemistry at the University of Pennsylvania. This monograph contains fourteen pages and a portrait of Rogers; it is issued with the imprint of the University of Pennsylvania. Doctor Smith tells in his usual charming manner of the life and work of a Philadelphia chemist who was closely affiliated with two of her leading institutions of learning, the University of Pennsylvania and The Franklin Institute. J. S. H.

On the Nature of Light. E. O. LAWRENCE and J. W. BEAMS. (*Proc. Nat. Acad. Sciences,* April, 1927.)—This investigation was made for the purpose of finding something about the length of light-quanta. A very ingenious device was employed by which pulses of light of short duration were produced by the use of two Nicol prisms and two Kerr cells for the modification of the light coming from a spark gap. In this way light passed through the optical valve for the exceedingly small interval requisite for the transmission of electrical effects along a length of wire varying from 4 to 40 metres. The emerging light fell upon a very sensitive potassium photo-cell where the effects were studied in relation to the duration of the light pulses causing them.

The conclusion is reached that "If light-quanta are of the commonly understood wave nature, they are less than 3 cm. in length and an electron absorbs a light-quantum photo-electrically in less than 10^{-10} sec." This conclusion is contrary to the outcome of a line of reasoning followed by H. A. Lorentz according to which a quantum has considerable extension both in length and breadth. It is, however, supported by the findings of G. P. Thomson. The authors interpret their results as agreeing with a theory of light advanced by W. F. G. Swann, Director of the Bartol Laboratory, as well as with a more recent theory proposed by Sir J. J. Thomson according to which light contains both quanta and waves. G. F. S.

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